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BALLOON RISK ANALYSIS REPORT

For

ANTARCTICA BALLOON MISSIONS
Winter 2018/19 Campaign
Revision A

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803/Safety Office

National Aeronautics and Space Administration

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CHANGE HISTORY LOG		
REVISION	EFFECTIVE DATE	DESCRIPTION OF CHANGES
-	October 01, 2018	Baseline
A	October 7, 2019	Campaign refly of missions, updated to reflect current failure rates, phase distributions, and resulting risk values. Added section to assess risk associated with Small Super Pressure balloon systems to be launched.

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1.0 INTRODUCTION

A balloon risk analysis has been performed to evaluate the safety risk to the public associated with the following missions to be launched from Antarctica: 1) BLAST (Devlin), 2) SuperTiger (Binns), and 3) XCaliber (Krawczynski). These missions are zero pressure Long Duration Balloon (LDB) missions. The possible launch window extends from November 2018 through January 2019. Columbia Scientific Balloon Facility (CSBF) based in Palestine, TX will conduct these missions. The missions are planned such that wind conditions should keep the trajectories over the continent of Antarctica for a significant period of time. Mission specific data can be reviewed in the Balloon Risk Analysis Data Sheets provided by the Balloon Program Office (BPO), which are included as Enclosures #1 through #3 of this document. The risk analysis methodology utilized for Antarctica is unique because the Riskgridbuilder program method cannot be properly or easily applied. Therefore, the risk calculation is based upon what is considered a worst case trajectory. This methodology will only be used for Antarctica and not for any other launch site.

Also included in this review is a hybrid qualitative assessment of the small scale Super Pressure Balloon systems to be launched- two mission for TravalB. The data sheets can be found at \\wff-lynx\Code803New\Documents\Working Documents\Flight Safety\Range Users FSDP\Balloons\Antarctica 2019\Datasheets.

This document compares the data used from the 2017 New Zealand Balloon Campaign for launching Super Pressure Balloons (SPB) and this document to assess the risk associated with launching these small systems. The risk analysis report for that campaign “803-FS-RAR-BPO-NZ2017-SPB-01” can be found at \\wff-lynx\Code803New\Documents\Approved Safety Documents\Risk Analysis Reports\Flight Safety RARs\Balloons. Refer to that risk analysis for more in-depth discussions on the assessment process not contained herein.

2.0 RISK CRITERIA

The primary safety risk criterion for this mission is casualty expectation. Section 6.2.1.2 of the 2002 Range Safety Manual Revision C establishes that the casualty expectation (E_c) shall be $\leq 100 \times 10^{-6}$. For missions where the CE risk exceeds this criterion, a waiver from the Code 800 Director is required. Additionally, there is a criterion that states the Probability of Casualty (P_c) for individuals shall be less than or equal to 1×10^{-6}. This criterion shall be assessed for impacts in Antarctica.

3.0 RISK ANALYSIS INPUT VALUES

The WFF 2000 Balloon Risk Model calculates risk for ascent, float, and descent/impact phases of flight for a conventional balloon mission. These phases of flight will be flown within the continental boundary or over the ocean. The following sections address the inputs to the model.

The analysis of the launch phase provides the rules and constraints needed to contain the associated hazards and thereby prevent exposing people to the hazards. Risk to Critical Operations personnel who are not essential to the launch operation, but are located in the Launch Hazard Area is addressed through risk assessment (see Section 4.2.2). Risk to launch essential personnel is addressed by positioning them in a way that minimizes their exposure to the launch hazards. The analysis of launch process is addressed in Section 4.1.

3.1 MISSION FAILURE PROBABILITIES

The Antarctica 2018/19 missions are all conventional zero pressure balloons with hardware being utilized for Long Duration Balloon (LDB) missions. The mission failure probability of 44% and standard distribution apply for ascent, day 1 of float and descent/impact phases. These values are used in the Balloon Risk model to calculate the CE values. The extended float phase of days 2-N require an additional failure rate by hour be applied for those expected days of float. This data is presented in the table that follows (Table 3.1.1).

The updated failure probability is based on analysis provided in 803-FS-RAR-BPO-FTSUM19-01A Section 4.2.2 which can be found at \\wff-lynx\Code803New\Documents\Approved Safety Documents\Risk Analysis Reports\Flight Safety RARs\Balloons.

Table 3.1.1 Probability of Failure and Phase Distribution

Event	Probability of Occurrence
Ascent Failure	0.44 x 0.6436 = 0.2832
Float Failure – Day 1	0.44 x 0.3078 = 0.1354
Extended Float Failure – Days 2-N	0.048* per day
Descent Failure	0.44 x 0.0486 = 0.02143

*Represents an hourly failure rate of 0.002. For a 59 day extended float, the failure probability is calculated as follows: $P_f = 1 – \exp[-(0.048 * 59)] = 0.941$

3.1.1 Small Scale Super Pressure Balloon Systems – Failure Probabilities

A one-to-one comparison cannot be made between the two analysis processes as Super Pressure Balloon systems have an added phase (pressurization) for analysis. However, Safety believes the similarities can be compared and judgements made to move forward with an analysis.

Reviewing the risk analysis report from the 2017 New Zealand Campaign, 803-FS-RAR-BPO-NZ2017-SPB-01, the following failure rates were used to determine risk values.

Table 3.1.1-1 2017 New Zealand Failure Probabilities by Phase and Comparison to ZPB values

Risk Grid	SPB Failure Rate	ZPB Failure Rate
Ascent Below 15,000 feet	0.0142	0.0354
Ascent Above 15,000 feet	0.0901	0.2780
Total Ascent:	0.1043	0.2832
Pressurization	0.3635	N/A
Float	0.0016 per hour*	0.002
Float (after mission anomaly)	0.0035 per hour	N/A
Descent	0.0171	0.0214

*Represents an hourly failure rate of 0.002. For a 99 day extended float, the failure probability is calculated as follows: $P_f = 1 – \exp[-(0.048^* 59)] = 0.991$

Since failure probabilities are direct inputs to the Ec equation, using a ratio would approximate the resultant risk within a reasonable margin of error. The balloon risk model used to calculate risk values does not have the capability of dividing the ascent portion into two parts. Therefore the more conservative ratio will be applied to the entire phase. The pressurization phase is considered the most dynamic phase of flight for super pressure balloon missions and therefore the most risky. ZPB missions do not have this phase therefore there are no values to reference. However, risk values will be approximated in Section 4.3.

3.2 RISK REDUCTION FACTORS

Risk reduction factors (RRF) have not been re-evaluated since the FY2015 analysis as no information has been received to justify different values for the parameters relating to protection, surveillance, and pickling. Structural protection values used were for standard zero-pressure missions in Antarctica and are presented in Table 3.2.1. The values represent the effectiveness of a structure to protect against an impact. Surveillance is not anticipated to be provided at termination. Thus, effectiveness values of 0% have been used in the analysis. In this analysis, pickling effectiveness has been set to 0%. The values used for surveillance and pickling are also presented in Table 3.2.1.

The probability to detect and avoid is a containment measure that must be taken by individuals in the general population. Therefore, it is assigned a value of zero effectiveness. The values used for the percentage of people indoors used in the balloon risk model have been adjusted to allow for the extreme climate and the likelihood virtually all populations are indoors almost all the time. See Table 3.2.2.

Table 3.2.1 Structural Protection Factors, Surveillance, and Pickling (% effectiveness)

	PRO(structural protection)	SUR(surveillance)	PIC(pickling)
Balloon	90%	0%	0%

Payload	10%	0%	0%

Table 3.2.2 Detect and Avoid Probability values and Percentage of People Indoors values

	P(Detect and Avoid) (% effectiveness)
Balloon	0%
Payload	0%
Percentage of People Indoors (for day missions in Antarctica)	
	90%

Town and city avoidance factors (TCFs) were assigned a low value of 0.01 as all populations are located in an identified 'town' or science station or science camp.

No changes will be made to the assumptions for risk reduction factors such as structural protection in the risk assessment process for the small scale super pressure systems.

3.3 POPULATION DATA

The ascent radius of 69.05 statute miles (60 nm) was determined from an average of approximately 60 balloon trajectories sampled for Palestine, TX. McMurdo Station is near the launch site. The population is around 2000 at its peak. In terms of Ec, the most conservative trajectory would fly over McMurdo, which is the only significant population center within 60 nm of the launch site. To mimic the methodology utilized by Risk Grid Builder, the ascent trajectory overflies 1 nmi^2 cells. The overflight area for ascent then is 60 nmi^2. Therefore, population density for the conservative trajectory ascent area = 2,000/60 nmi^2 = 33.4 people/nmi^2, or 25.2 people/mi^2.

The population for the continent is approximately 4,617 at its peak level during the summer based on data obtained from the Council of Managers of National Antarctic Programs (COMNAP). A spreadsheet showing the populations of the science camps has been provided to the MRSO. A map showing the locations of the science camps is given in Enclosure 4. For float and descent, the Antarctica population of 4617 people was used for determining population density. The circumferential distance at 70° S latitude is approximately 7712 nmi. Many of the science camps are at or around 70° S. For conservatism, the Antarctica population is rounded to 5000 people. Employing the same method as presented in the previous paragraph for determining the most conservative trajectory, the float population density was density was determined to be = 5000/7712 nmi^2 = 0.65 people/ nmi^2, or 0.49 people/mi^2. This approach is very conservative because it assumes that all science camps will be overflown during one circumnavigation of Antarctica.

3.4 LETHAL AREAS

The WFF Balloon Risk Model, using the payload/balloon characteristics provided by the Balloon Program Office (see Enclosures #1 - #3), calculated the following lethal areas for the payload. The balloon lethal area was calculated based on the approved methodology detailed in Enclosure #5. This analysis inferred credible foot print areas from balloon and payload impact location data. The following data will be used to calculate the risk values presented in Section 4.0. For payloads, the information presented is from the largest face.

Table 3.4.1 Lethal Areas for Missions

	Scientist/Payload	Lethal Area (ft^2/m^2)		Balloon Weight (lbs./kg)
		Payload	Balloon	
1	Binn/Super TIGER	630*/ 58.5	727.2 / 67.6	4040 / 1834
2	Krawczynski/XCaliber	614.3/57.1	727.2 / 67.6	4040 / 1834
3	Devlin/BLAST	877.5/81.5	917.3/85.2	5096/2311.5

*****Payload height includes rotator for all payloads.

Table 3.4.2 Lethal Area for Small SPB missions

	Scientist/Payload	Lethal Area (ft^2/m^2)		Balloon Weight (lbs./kg)
		Payload	Balloon	
1	Salter/TRAVALB	73.8/ 6.9	49.1 / 4.6	273 / 123.9

The small super pressure balloon is 0.6 MCF in volume with an estimated weight of 273 lbs. which falls outside of the definition for small balloons documented previously therefore no special risk reduction for structural protection will be factored into the assessment.

Table 3.4.3 Ratio for Lethal Area comparisons to Antarctica ZPB

Scientist/Payload	Lethal Area (ft^2/m^2)		Balloon Weight (lbs./kg)	Ration for Payload Lethal Area	Ratio for Balloon Lethal Area
	Payload	Balloon			
Devlin/BLAST	877.5/81.5	917.3/85.2	5096/2311.5	1.0	1.0
Salter/TRAVALB	73.8/ 6.9	49.1/4.6	273 / 123.9	0.08	0.05

4.0 RISK ANALYSIS

4.1 LAUNCH AREA RISK

The personnel risk associated with the launch phase deals with failure events that could occur after spool release of the balloon. The focus of this risk analysis centers on four pieces: the payload launch vehicle, the balloon that can lift or drag the payload, the parachute that can act as a sail and drag the payload launch vehicle, and the payload that can tumble given enough forward momentum.

The payload launch vehicle hazards are addressed in the Ground Safety Risk Analysis Report and Ground Safety Plan. The Ground Safety Risk Analysis Report contains ground operations Hazard Analysis Reports (HARs). These HARs involve the payload and/or launch vehicle. For a more detailed description, refer to the Ground Safety Risk Analysis Report. A Pre-Launch Danger Area (PLDA) and a Launch Danger Area (LDA) are created based on those hazards and only mission-essential personnel are permitted in the LDA. The WFF safety risk analysis process is documented in 800-PG-8715.5.1, Chapter 2.

In addition to the aforementioned HARs, there are HARs specific to the balloon and payload after flight is achieved that relate directly to Flight Safety. The risks associated with these HARs shall be mitigated to an acceptable level with processes implemented by this document. The HARs shown in Table 4.1.1 below are only relevant to flight safety risks. The actual HRs are provided in Appendix A.

Table 4.1.1 Hazard Analysis Report Listing of Flight Safety related Hazards as of 7/20/2018

HR#	HAZARD	PROBABILITY	SEVERITY	RAC
HR-5	Mechanical Failure of the flight train	E	I	3
HR-14	Insufficient lift in Balloon System	E	I	3
HR-17	Collar fails to release during launch	E	II	3
HR-18	Crew Member Falls off Launch Vehicle (LV)	E	I	3
HR-19	Cables of the Flight Train become entangled in the superstructure of the Launch Vehicle (LV)	E	I	3
HR-20	Flight Train or Payload Impacts Launch Vehicle (LV)	E	I	3
HR-21	P/L Launch Head Release Mechanism Fails	E	I	3
HR-22	Balloon strikes ground and p/l is damaged due to late release	D	II	3
HR-23	LV Motor Stalls	E	II	3
HR-24	Personnel/Equipment Run over by LV during or after Launch	E	I	3
HR-29	Balloon burst during ascent or float phases	E	I	3
HR-30	Terminate system fails leading to a derelict balloon	E	I	3
HR-31	Premature termination caused by thunderstorm activity in the area of the balloon during flight	E	I	3
HR-32	Critical flight control telemetry loss	E	I	3
HR-33	Critical flight command control capability loss	E	I	3
HR-34	Balloon Aircraft collision	E	I	3
HR-38	Balloon or payload impact personnel or property following flight termination	E	II	3
HR-39	Balloon launch abort operations	E	II	3

RAC 1 Operation Prohibited: Risk must be reduced to a RAC 2 or RAC 3

RAC 2 Waiver Required for Operation
RAC 3 Operations Permissible

Given that a malfunction event occurs that calls for a termination, then a worst-case scenario would be the three balloon pieces free to move unencumbered. For the launch phase risks a containment approach will be used that relies on timely activation of the Balloon Termination System in the event of a launch failure and restricting or prohibiting access to the various hazard areas as described below.

The Balloon Program Office and Code 543 (R. Farley) have provided additional drift data for an aborted balloon based on findings from the Australia incident (April 2010). The analysis is documented in a PowerPoint presentation by Mr. Farley, “Distributed Balloon Impact Loads from Launch Aborts.” Using documented assumptions and simulations, an aborted balloon is predicted to drift the distances listed in Table 4.1.2 from the point of termination before impacting the ground. It is assumed this data is valid for an aborted or terminated balloon at the Mobile Launch Vehicle prior to payload release or with one or two seconds after payload release. The data was derived from the drift distance from the April 2010 incident at a wind speed of 13.4 knots. The other values were extrapolated from this data point.

Table 4.1.2

Distance Traveled by Aborted Balloon at Spool or Launch prior to payload release	
Wind Speed (knots)	Distance Traveled (feet)
16	4023.9
13.4*	3370
12	3017.9
6	1509
5	1257.5
2	503

NOTE: This data assumes an abort or termination of the balloon at the spool or the launch platform prior to the payload being released.

* Data extrapolated from 4/2010 incident.

4.1.1 Factor of Safety

The Launch Hazard Area is to be applied based on wind speed. A Factor of Safety (FOS) of 1.5 is applied to the wind drift distance to account for any uncertainties since only one data sample is available. This creates a buffer which is then applied to calculate the LHA distances for various wind speeds. The following table presents the LHA areas, the corresponding wind speeds, the BPO provided wind drift table data and calculations for the Factor of Safety in applying the LHA. The Factor of Safety applies to the protection of the public outside the LHA. Because the location of the payload launch vehicle is not known prior to actual launch, an estimation of the point at which the vehicle may be at launch that is closest to the public has been used in the calculations. In Antarctica, there is no ‘public’ as per NASA’s definition, but there are Critical Operations Personnel and Mission Essential Personnel to protect via the Launch Hazard Area.

Assumptions:

1) Payload Launch Vehicle is at 'center' of launch pad layout direction junction.
2) The LHA direction is plotted about the launch direction.
3) Buffer distance assumed is approximately 1000 feet run with payload launch vehicle.

Table 4.1.3 Safety Factors for the Various Wind Speeds

Wind Speed (knots)	Drift Distance (feet)	Factor of Safety (FOS)	LHA Radius = (Drift Distance * FOS) + Buffer	LHA Shape
2	503	1.5	1755 ft / 0.29 nm/0.33 mi / 0.53 km	360° about launch direction
6	1509	1.5	3264 ft / 0.54 nm/0.62 mi / 1.00 km	±60° about launch direction
12	3018	1.5	5527 ft / 0.91 nm/1.05 mi / 1.68 km	±45° about launch direction
16	4024	1.5	7036 ft / 1.16 nm/1.33 mi / 2.14 km	±30° about launch direction

NOTE: This data assumes an abort or termination of the balloon at the spool or the launch platform prior to the payload being released.

4.1.2 Launch Hazard Area

A Launch Hazard Area (LHA) shall be enforced about the launch point – that being the original point of the payload launch vehicle. The center of the launch pad shall be used as the origination point of the LHA for the purposes of coordinating the roadblock and sheltering. The LHA shall be a set of graduating circular sector areas based on wind speed and Factor of Safety. The placement of the graduating circular sector areas shall be based on real-time wind conditions the day of the launch attempt. See Table 4.1.4.1 for size and shape of the LHA based on the wind speed.

One roadblock shall be placed on the road to the LDB site during the inflation process to control personnel flow. The roadblock will be placed on the road from McMurdo Station to Williams Field at the juncture to the LDB site prior to the completion of inflation to control personnel flow. Traffic may continue between McMurdo and Williams Field, but not to the LDB site. This reflects a change in the LDB site, extending the road and moving the LDB farther away from Williams Field. See Enclosure #6 and for graphical representation of the launch site layout, including Launch Limit Area (LLA) and Launch Danger Area (LDA).

There is an initial circle that extends 0.29 nmi (1,755 feet) out from the center of the launch pad and is applied for extremely light and variable winds as seen by inspection of Table 4.1.4.1. The circular sector areas or enclosed arcs described in the following section are to be aligned along the layout azimuth in the direction of the predicted drift at launch. To explain further, if the layout direction is 180° for the launch toward 360°, the circular sector areas would be aligned toward 360°.

The first circular sector area or enclosed arc (corresponds to 6 knot wind speed) extends 0.54 nm (3,264 feet) out from the center of the launch pad and sweeps ±60° on either side of the nominal layout direction. The second circular sector area or enclosed arc (corresponds to 12 knot wind speed) extends 0.91nm (5527 feet) out from the center of the launch pad and sweeps ±45° on either side of the nominal layout direction. The third and last circular sector (corresponds to 16 knot wind speed) area extends 1.16nm (7036 feet) out from the center of the launch pad and sweeps ±30° on either side of the nominal layout direction. These sections are depicted graphically in Enclosure 7 in the West layout direction. Enclosure 6 depicts the launch layout for the launch area buildings relative to the launch pad. The ice shifts a little each year, so Enclosure 7 would need to be updated when a CSBF personnel are able to survey the launch location, since Enclosure 7 provides coordinates for the launch location and Payload Building #1. Enclosure 6 is not expected to change much, since the ice drift will still maintain the positions of the buildings and launch pad relative to each other.

The LHA is to be oriented along the layout direction with the circular sector areas radiating towards launch direction. The requirement for sheltering personnel can then be determined based on the wind speed and direction of the current pibal data. This process is to be performed with each pibal report until launch. There shall be a table to aid the implementation of the LHA with respect to center essential personnel at the LDB site at Williams field to allow for some variability in wind data. This will be detailed in the flight safety plan.

4.1.2.1 Launch Hazard Area for Small Scale Super Pressure Balloon Systems

Discussions with BPO and CSBF have concluded that the small super pressure balloon systems will not be conducted in ground wind speeds greater than 6 knots. This may not directly correlate to the vector summation of the winds traditionally provided to the MRSO, which determines the appropriate LHA arc to apply. As a conservative and simple measure to ensure the hazards associated with an active abort for small balloon launches are mitigated, the 12 knot LHA arc shall be applied for all small balloon launches. This accounts for the standard assumptions regarding the expected balloon carcass distance traveled and also provides necessary buffer. Small balloon systems have potential to be at a slightly higher altitude than standard ZPB since during the active abort sequence, the entire system rises after spool (hutch-clutch) release. It is expected the balloon carcass may separate at a higher altitude if it is terminated at the LLA than traditional ZPB systems, and therefore applying the 12 knot LHA arc was deemed sufficient to contain the balloon carcass debris.

The 12 knot LHA shall be aligned along the layout azimuth in the direction of the predicted drift at launch.

4.1.3 Launch Limit Area

A Launch Limit Area (LLA) of 1000 ft. shall be enforced about the launch point where the payload launch vehicle is stationed at the time the spool releases the balloon. Only mission essential personnel are allowed in that area. All mission essential personnel involved in launching the balloon shall remain upwind of the payload launch vehicle out of the drive path. If this is not possible based on launch duties, that person must be in communication with the payload launch vehicle driver and at least 50 feet away from payload launch vehicle. The exception is for persons inside and on the payload launch vehicle keeping the payload under control and manually pulling the launch pin. All personnel must endeavor to detect and avoid a hazard to mitigate the launch risk.

4.1.4 Launch Danger Area

A Launch Danger Area (LDA) of 500 ft. shall be enforced about the LLA per the Ground Safety Plan. The Launch Danger Area has been sized to contain the parachute the flight train and the payload given that the balloon is launched unsuccessfully and the MRSO calls for an abort at the maximum extent of the LLA resulting in a separation of the balloon from the parachute and payload (use of BTS). The 500 ft. is the distance from the payload to the top of the parachute (315 ft.), the distance it would take to abort the balloon (50 ft.), and safety buffer of 135 ft. The LDA is designed to protect the mission essential personnel and range essential personnel that are inside the LHA but outside the LLA from the parachute and the payload.

Those individuals will be either sheltered or just outside one of the payload assembly buildings as approved by the MRSO. Those individuals will head into the payload assembly buildings if the balloon begins to drift towards their location. All personnel must endeavor to detect and avoid a hazard to mitigate the launch risk.

Confidence in the successful separation of the balloon from the parachute/payload (use of BTS) is based on preflight checkouts and testing and highly reliable operation in over 25 years of flight history.

The launch limit area (LLA) and Launch Danger Area (LDA) remains the same as standard ZPB missions from LDB site, Antarctica. Please refer to 803-GS-GSP-BPO-Antarctic-2019-01 for a description of this area. It is important to note that for the small balloons, a mobile launch vehicle is not used. A simple spool system exists to hold the balloon bubble during inflation, and launch occurs after release from the spool. To be conservative and consistent with the standard ZPB systems, Ground Safety evaluated the differences, and has concluded existing hazard areas and restrictions provide sufficient mitigation for those hazards listed in the hazard analysis reports. The launch crew handling the payload and Micro-Instrumentation Package (MIP) are not permitted to cross the LLA and still conduct the launch. Both passive and active aborts can be conducted with the small balloon systems. CSBF has the ability to activate the Balloon Termination System (BTS) from within the hazard area prior to the system leaving the LLA. Therefore, only mission essential personnel are permitted inside. All mission essential personnel involved in launching the balloon shall remain upwind of balloon system during the launch. The only exceptions are for the launch crew who are tasked with handling the payload. All mission essential personnel required to remain in the LLA shall endeavor to detect and avoid any hazards.

4.2 CONTROLLED ABORT

A controlled abort is defined as an abort of the balloon and payload with the balloon/payload still attached to the launcher. The probability of conducting a controlled abort was given by BPO as 2.3%. Two mitigation strategies are discussed in the subparagraphs below: 1) sheltering, and 2) impact risk assessment. For further details on the risk mitigation strategy, refer to the flight safety plan at \\wff-lynx\Code803NEW\Documents\Approved Safety Documents.

No additional data has been provided for controlled aborts for small scale balloon systems including SPB systems. It is believed that due to the greatly reduced size and weight of the small scale systems, all sheltering requirements are more than adequate as a risk mitigation.

4.2.1 Sheltering

A structural analysis was performed for the payload buildings. At this time the effectiveness of sheltering is questionable in the event of a controlled abort for a side-on impact abort based upon structural protection studies recently completed. Therefore, structural protection cannot at this time be counted upon to protect personnel within the payload assembly building(s) in the event of a controlled abort. The only acceptable mitigation to a controlled abort is discussed in Section 4.2.2, below.

4.2.2 Controlled Abort Risk Calculations

RSM 2002 Rev. C 6.2.2.2 provides a separate risk criterion for mission essential personnel. It states that the casualty expectation (Ec) for mission essential and critical operations personnel shall be less than 300×10^{-6}. RSM 2002 Rev. C 6.2.1 also provides a criterion for mission essential and critical operations personnel that states the Probability of casualty (Pc) for individuals shall be less than 10×10^{-6}. These two criteria shall be addressed for the launch area in the following discussion.

To assess the likelihood of an injury (i.e. casualty expectation), assumptions were made for the purpose of calculating a risk value for the launch area. The Launch Hazard Area ranges between 1755 ft. and 7036 ft. in distance from the center of the launch pad in any direction and varying azimuth ranges. The arc applied is based on the layout direction and launch direction as provided in Table 4.1.3. A sample analysis uses the 7036 ft. dimension for the LHA sector of +/- 30° (or 60°total) to calculate the population density as it captures all personnel in the area. During launch, mission essential personnel will be on the launch pad (on launch vehicle), at spool vehicle, at inflation equipment, at the edge of the LLA perpendicular to the launch vehicle, and in two buildings. Mission essential personnel only will be within the worst case area sector. Therefore, the equation $A=1/2r^2\theta$, will be used to calculate the area; where θ is the LHA arc in radians corresponding to the LHA distance, as provided in Table 4.1.3. The lethal area of the balloon is estimated at 2000 ft^2 which is conservative based on the uncertainty of the descent physics of the balloon at the lower altitudes and lack of full deployment.

7036 ft. = 1.33 mi (statute mile)
$\theta = \pm 30°$ about the launch direction = $60° \bullet \pi/180° = 1.047$ radians
$A = 1/2 \bullet r^2\theta = ½ \bullet \pi/3 \bullet (1.33 \text{ mi})^2 = 0.926 \text{ mi}^2$

Assuming 40 people who are mission essential personnel, a population density is calculated:

PD = Population / Area (mi^2)
PD = 40/0.926 mi^2 = 43.19 people / mi^2

To calculate the risk value, we use the basic equation:

CE = PD * A_L * Pf * RRF
Where

- PD = Population Density
- A_L = Lethal Area, this is the balloon only as explained in the discussion above
- Pf = Probability of failure
- RRF = 1, there are no risk reduction factors applied in the calculation

The lethal area must be converted to mi^2 (statute miles) to be in units consistent with the population density. That conversion is included in the algorithm. The probability of an abort for conventional zero-pressure balloons is 2.3% based on a database provided by BPO personnel. From the database, there have been 680 zero pressure balloon launches since 1986. Of this total, 8 were reported as active aborts. Using the exact form of the binomial distribution, one obtains 2.31% as an upper bound at 95% confidence. Active abort includes any situation where the balloon is aborted after spool release but prior to payload release. This value is not included in the mission failure rate as an aborted mission is not considered to have reached the ascent phase and thus does not qualify to be included in those figures.

Lethal area must be re-expressed in terms of square miles, rather than square feet.

$A_L = 2000 \text{ ft.}^2 * (1 \text{ mi}^2 / (5280 \text{ ft.})^2) = 7.174 \times 10^{-5} \text{ mi}^2$

Using the equation and filling in the appropriate values we have for following risk value equation for the sample problem:

CE = 43.19 people/mi^2 * 7.174×10^{-5} mi^2* .023 * 1
<u>CE = 71.26×10^{-6}</u>

CE values for controlled abort for all the wind speeds in Table 4.1.3 are provided in the following table:

Table 4.2.2.1 CE Calculation for Mission Essential Personnel

r (Table 4.1.3)	θ (radians, π/180°)	Area (1/2θr²)	PD (40/Area)	CE = PD * A_L * Pf
0.33 mi	2π	0.342 mi^2	116.92 people/mi^2	192.9 x 10^{-6}
0.62 mi	2/3π	0.403 mi^2	99.37 people/mi^2	164.0 x 10^{-6}
1.05	1/2π	0.866 mi^2	46.20 people/mi^2	76.2 x 10^{-6}
1.33	1/3π	0.926 mi	43.19 people/mi^2	71.3 x 10^{-6}

These risk value are specifically for the launch area and calculated for mission essential personnel. They meet the criterion of less than 300 x 10^{-6} for casualty expectation for mission essential personnel. The value does not apply to public risk.

The second criterion to asses is the probability of casualty (Pc) for individuals. The primary area of concern is the LHA that overlays the buildings used for sheltering in the past. This analysis will use that area to calculate a Pc value for the launch area. The lethal area of the balloon is estimated at 2000 ft^2 as it will not have time to ball up during descent, but come down more as a streaming balloon.

To get total Pc for the controlled abort, use $P_c = P_{injury} * P_i * P_{failure}$. This technique is more fully explained in Section 4.4 below.

$$P_c = \frac{A_{lethal}}{A_{cell}} * \frac{\cancel{A_{cell}}}{2 * pi * Sx * Sy * e^{(-1/2*[(\frac{x}{Sx})^2 + (\frac{y}{Sy})^2])}} * P_{failure}$$

Sx= 1 sigma x dispersion = 1 nmi (for ascent < 15 kft, refer to 4.4 below)
Sy= 1 sigma y dispersion = 1 nmi
X= downrange separation distance of target = 0 nmi
Y= crossrange separation of target = 0 nmi

Pf = 0.023 based on information provided by BPO for a controlled abort.

Pc = 8.622x10^{-6} • 0.023

Pc = 2.59 x 10^{-7}

This value meets the criterion of less than 10 x 10^{-6} for probability of casualty for individuals for mission essential personnel.

4.3 CASUALTY EXPECTATION VALUES

The E_c values for the Devlin/BLAST mission with launch/ascent, float, and descent/impact on the continent of Antarctica are provided in the tables below. The Devlin/BLAST mission was chosen because of all the missions being launched on this campaign, it has the largest values for balloon and payload lethal areas, so this mission will have the largest E_c values. Of the 3 missions, the Binn/SuperTiger mission has the longest desired float time, so this value was chosen as the float duration in the table below. All values are for day operations since the months November to January correspond to summer in the Southern Hemisphere. During the summer, the area within the Antarctic Circle will experience almost continual daylight.

4.3.1 Devlin/BLAST Casualty Expectation Values

Mission Phase	Balloon Ec x 10^{-6}	Payload x 10^{-6}	Casualty Expectation (E_c) x 10^{-6}
Launch/Ascent (<60 nmi)	13.28	60.82	74.10
Float (1 day)	0.31	1.48	1.79
Extended Float (2 – 60 days)	2.17	10.26	12.43
Descent	0.02	0.08	0.10
TOTAL	15.78	72.64	88.42

Applying the ratios documented in Section 3.1.1 for failure probabilities and Section 3.4 for lethal areas, the following risk values have been calculated for the Small Scale Super Pressure Balloon missions.

4.3.2 Small Scale Super Pressure Balloon mission - Balloon Casualty Expectation Values

Mission Phase	Balloon Casualty Expectation From Blast (E_c) x 10^{-6}	Ratio for Failure Probability	Ratio for Lethal Area	Balloon Casualty Expectation For TravalB (E_c) x 10^{-6}
Launch/Ascent (<60 nmi)	13.28	0.4	0.05	0.27
Float (1 day)	0.31	0.8	0.05	0.01
Extended Float (2 – 99 days)	2.29	0.8	0.05	0.09
Descent	0.02	0.8	0.05	0.0008
TOTAL	15.90			0.37

4.3.3 Small Scale Super Pressure Balloon mission - Payload Casualty Expectation Values

Mission Phase	**Payload Casualty Expectation From Blast (E_c) x 10^{-6}**	**Ratio for Failure Probability**	**Ratio for Lethal Area**	**Payload Casualty Expectation For TravalB (E_c) x 10^{-6}**
Launch/Ascent (<60 nmi)	60.82	0.4	0.08	1.95
Float (1 day)	1.48	0.8	0.08	0.09
Extended Float (2 – 99 days)	10.81	0.8	0.08	0.69
Descent	0.08	0.8	0.08	0.005
TOTAL	73.19			2.73

To account for the risk associated with the pressurization phase, an assumption is made based on the failure probabilities applied in the New Zealand analysis and extrapolated in this analysis using the ascent phase risk. The ratio of failure probabilities between pressurization and ascent is 3.5. Using this as a multiplier to the ascent risk approximates the pressurization risk. This is included in Table 4.3.4. The risk value was also recalculated based on 99 days of extended float.

4.3.4 Small Scale Super Pressure Balloon mission - Total Casualty Expectation Values

Mission Phase	**Balloon Casualty Expectation For TravalB (E_c) x 10^{-6}**	**Payload Casualty Expectation For TravalB (E_c) x 10^{-6}**	**Total Casualty Expectation (E_c) x 10^{-6}**
Launch/Ascent (<60 nmi)	0.27	1.95	2.22
Pressurization	3.5 *0.27 = 0.95	3.5*1.95 = 6.83	7.78
Float (1 day)	0.01	0.09	0.10
Extended Float (2 – 99 days)	0.09	0.69	0.78
Descent	0.0008	0.005	0.006
TOTAL	1.32	9.56	10.88

Based on the assumptions presented, the small scale super pressure balloon missions are well within the criterion. The missions meet the RSM-2002C requirement for E_c less than 100 x 10^{-6}, as given in Section 2.0 of this document.

4.4 PROBABILITY OF CASUALTY FOR INDIVIDUALS

Probability of casualty (P_c) for a single individual in all cases must not exceed $1x10^{-6}$. The worst case is assumed when the system is terminated (either commanded or uncommanded) and the predicted impact point is assumed to be at the center of a risk grid cell, which is assumed to be 1 nmi^2, and which results in the maximum risk to an individual also located at that point.

The risk was determined using the lethal area and probability of impact given dispersion. It is likely that the balloon and payload will impact at two separate locations, and therefore it is nearly impossible for one person to be struck by both pieces. Further, the horizontal range distance between the two impacts is such that the risk to an individual from the payload who is beneath the balloon impact point is insignificant and vice versa.

The lethal area used for the individual P_C calculations is the same as that used for the E_C calculations. A sweep out distance is accounted for. All factors are detailed in the following calculations.

The following basic equation was used to calculate P_c for the Ascent, Float, Descent, and extended Float phases.

$$P_c = P_{injury} * P_{impact} * P_{failure}$$

Where

P_c= Probability of Casualty for individuals

P_{injury}= Probability of Injury

P_i= Probability of Impact

$P_{failure}$= Probability of Failure

And

$$P_{injury} = \frac{A_{casualty}}{A_{cell}}$$

$$P_{impact}(A_{cell}) = \frac{A_{cell}}{2*pi*Sx*Sy*e^{\left(-1/2*\left[\left(\frac{x}{Sx}\right)^2 + \left(\frac{y}{Sy}\right)^2\right]\right)}}$$

Solving

, $$P_c = P_{injury} * P_{impact}(A_{cell}) * P_{failure}$$

$$P_c = \frac{A_{lethal}}{\cancel{A_{cell}}} * \frac{\cancel{A_{cell}}}{2*pi*Sx*Sy*e^{\left(-1/2*\left[\left(\frac{x}{Sx}\right)^2 + \left(\frac{y}{Sy}\right)^2\right]\right)}} * P_{failure}$$

$$P_c = P_{impact}(A_{lethal}) * P_{failure}$$

Person in the Open:

Calculate P_i for each case using PointPI:

Inputs:

A_{lethal}= Lethal Area of Balloon or Payload
Sx= sigma downrange dispersion
Sy= sigma crossrange dispersion
X= downrange separation distance of target from reference
Y= crossrange separation of target from reference

Where:

All cases:

A_{lethal} (balloon) = 917.3 ft^2 = 24.8E-06 nmi^2
A_{lethal} (payload) = 877.5 ft^2 = 23.8E-06 nmi^2
X = 0 NM; Y = 0 NM

Ascent below 15kft (Balloon and Payloads):

Sx and Sy = 1 NM

Balloon above 15kft (Balloon)

Sx and Sy = 1.25 NM

Payload above 15kft (Payloads)

Sx and Sy = 2.3 NM

Therefore:

Ascent below 15kft (Balloon):

P_i= 3.947E-06

Ascent below 15kft (Payloads):

P_i= 3.788E-06

Ascent above 15kft and all other cases (Balloon)

P_i= 2.526E-06

Ascent above 15kft and all other cases (Payloads)

P_i= 7.16E-07

For extended float, the probability of failure is 0.941, which cannot be used directly since it is too high a value that will result in a P_c that will exceed the 10^{-6} requirement. However, if we take notice of the fact in this case (i.e. extended float in Antarctica) that population will primarily reside in camps, a reduction of the extended float P_f based upon the dwell time over one of these camps, divided by the dwell time for a circumnavigation of the continent of Antarctica can be made. If a conservative velocity is assumed, dwell distances rather than dwell times may be compared. The circumference of Antarctica at 70°S is 7712 nmi or 14,283 km, see Section 3.3 above. A measurement was made across the McMurdo Station using Google Earth, which resulted in a distance of 5.6 km. To get a distance measurement for all the people in camps in Antarctica, the method of a ratio of the McMurdo population to total population to the ratio of the McMurdo distance to total distance was used.

$D_{total} = D_{McMurdo} \times (Pop_{total}/Pop_{McMurdo})$ = 5.6 km x (5000/2000) = 13.89 km

Therefore total dwell ratio = 13.89 km / 14,283 km = 9.72 x 10^{-4}

To get an adjusted failure rate for extended float, multiply 0.941 x 9.72E-04 = 9.15E-04. This value is still conservative for extended float since we are taking failure probability at the end of the extended float where the failure probability is the greatest, and which we assume to be 60 days. If extended float failure occurs at less than 60 days, the failure probability will be less than 0.941. See the note below Table 3.1.1 to see how extended float failure is determined as a function of float time.

1. Multiple the Probability of Injury and Probability of Impact by the Probability of Failure in order to calculate P_c for each case (see Table 3.1.1):

   $P_c = P_{impact}(A_{lethal}) * P_{failure}$

   Where:

   All cases:

   $P_{failure=}$

Ascent below 15kft	= 0.2832*(15kft/120kft) = 0.0354
Ascent above 15kft	= 0.2832 – 0.0354 = 0.2780
Float (1 day)	= 0.1345
Descent/Impact	= 0.0214
Extended Float	= 9.15×10^{-4}

2. Pc for People in the Open results:

   Pc (Devlin/BLAST Balloon):

Ascent below 15kft	= 3.947E-06*0.0354 = 1.4E-07
Ascent above 15kft	= 2.526E-06*0.2780 = 7.0E-07
Float (1 day)	= 2.526E-06*0.1354 = 3.4E-07
Descent/Impact	= 2.526E-06*0.0214 = 0.54E-07
Extended Float	= 2.526E-06*9.15E-04 = 2.310E-09

   Pc (Devlin/BLAST Payload):

Ascent below 15kft	= 3.788E-06*0.0354 = 1.3E-07
Ascent above 15kft	= 7.160E-07*0.2780 = 2.0E-07
Float (1 day)	= 7.160E-07*0.1354 = 1.97E-07
Descent/Impact	= 7.160E-07*0.0214 = 1.5E-08
Extended Float	= 7.160E-07*9.15E-04 = 6.551E-10

The Pc analysis was performed for the Devlin/BLAST mission because this mission has the largest payload and balloon lethal areas. Therefore, the other two missions would have lower Pc values since lethal area factors into the probability of impact calculation above. For all cases, the Pc criterion of 10^{-6} is not violated; therefore, the mission rules as executed by CSBF and the MRSO ensure the Pc criterion is satisfied for this mission.

The Pi values calculated for the TRAVALB balloon and payload are each smaller by an order of magnitude. Given the failure probabilities are not an order or magnitude greater, qualitative assessment shows the Pc values to be within the acceptable criterion.

5.0 SCOPE AND APPLICABILITY

The values presented in Tables 4.3.1 are applicable to the conventional CSBF zero-pressure balloon missions to be launched during the 2019/20 Balloon Campaign from Antarctica. They provide the upper bound of the risk to be accepted by the Code 800 Directorate for the Winter 2019/20 Balloon Campaign in Antarctica.

The values presented in Table 4.3.4 are applicable to the small scale super pressure balloon missions to be launched during the 2019/20 Balloon Campaign from Antarctica. They provide the upper bound of the risk to be accepted by the Code 800 Directorate for the Winter 2019/20 Balloon Campaign in Antarctica.

6.0 CONCLUSIONS AND RECOMMENDATIONS

For the Winter 2019/20 Balloon Campaign in Antarctica, the total mission risk for each individual mission meets the acceptable risk criterion of 100×10^{-6} for casualty expectation values. All missions specifically analyzed for risk as documented in this report are acceptable.

The Safety Office recommends that the Winter 2019/20 Balloon Campaign in Antarctica conventional zero pressure missions and small scale super pressure balloon missions documented be approved. The Flight Safety Plan shall state the missions within the acceptable criteria. Any test flights, special missions, or missions that are beyond the scope of this report require a separate analysis.

It is recommended that launch of the small scale super pressure balloon missions should not occur if the pressurization phase is predicted to occur over McMurdo Station. This serves as a risk mitigation strategy to account for possible incongruities between applying the conventional ZPB risk to the small SPB missions in the risk assessment process.

7.0 REQUIREMENTS

The risk values as calculated have taken the following restrictions into account:
1) The standard operating procedures must be employed during the termination phase. Those standard operating procedures include:

a) Class 1 towns (population less than 500) may not be directly under the predicted impact point but may be within the impact area.
b) Class 2 cities (population 500-4000) must be outside of the impact area but may be within the buffer area.
c) Class 3 cities (population greater than 4000) must be outside the buffer area.
e) The buffer area is the additional 5nm ring about the impact area for a total of 10nm about the predicted impact point.
f) Termination will not be initiated within 2nm of any town.

2) At launch, only mission essential personnel shall be allowed in the Launch Limit Area: Those personnel include the following:

a) Two payload handlers (2)- May be adjusted based on need for small scale missions.
b) Spool release handler (1)
c) Launch Crew Chief (1)
d) Payload Launch Vehicle Driver (2)- Not required for small scale missions
e) OSS (1)
f) MRSO (1)
g) CM (1)
h) MM (1)
i) Minimum number of other launch - essential personnel as per Range Safety Manual 2002 Revision C Section 5.2.3.

3) All mission essential personnel in the Launch Hazard Area must be kept sheltered in approved structures Payload Assembly Buildings with the exception of those personnel located at the spectator viewing area next to the Payload Assembly Building furthest from launch pad which is approved by the MRSO. Refer to the flight safety plan at \\wff-lynx\Code803NEW\Documents\Approved Safety Documents\Flight Safety Plans\Balloons for further details.

4) All other personnel shall remain out of the Launch Hazard Area (at the proscribed spectator area) or sheltered until such time as either of the following conditions exist:

a) The balloon and payload have launched and ascended out of the Launch Hazard Area and the "All Clear" is given by the responsible authority monitoring the trajectory in the tower.
b) The balloon, parachute, and payload have all come to a rest given an aborted launch attempt has occurred and the "All Clear" is given by the responsible authority monitoring the trajectory in the tower.

ENCLOSURE 1: SUPER TIGER BALLOON RISK ANALYSIS DATA SHEET

DATE: 13 September, 2019

Balloon Mission Identification: SuperTiger, Antarctica 2018/2019
Is this a Test Flight: No
Balloon Office Point of Contact: David Gregory Ph.# 757-824-2367
Scientist(s): Bob Binns
Launch Site: LDB Launch Site, Mcmurdo Antarctica
Latitude (deg.) = 77 S Longitude (deg.) = 167 E
Planned Launch Date: December 2018
Duration of Launch Window: Through Jan 20 2018

Payload/Balloon Characteristics

Gross Inflation Weight (lbs.): 11044
Stress Index: 1770
Suspended Payload Weight (lbs.): 6000
Payload Size (LxWxH) (ft.): 14 X 19 X 12 (FEET) *add 16' to height to include rotator and suspension
If cylinder – Diameter & Height (ft.):
Balloon Type: Zero-Pressure X Super Pressure
Balloon Volume (mcf.): W39.57
Balloon Weight (lbs.): 4040

Planned Flight Description:

Planned Duration of Balloon Flight (Hours/Days): >60 days
Balloon Launch and Ascent (Day – Night): Day
Balloon Float (Day – Night): Not expected to proceed past an Antarctic sunset
Float Time: (Max.) >60 day (Min.) 15 days
Float Direction (East-West-Turnaround): Generally Westward
Balloon/Payload Descent and Impact (Day – Night): Day
* For LDB and ULDB: N/A
1 – Sigma Latitude Variation (Degrees): 77S +/- 10 (will not leave continent)
Estimated Float Winds (Vel.-knots): Max. = Min. =
Mean = 29 from east 1 Sigma Variation = 11.1

Is this the first flight of a new balloon system? Yes _ No X If yes, please attach a theoretical reliability study.

SPECIAL REQUIREMENTS AND OTHER PERTINENT INFORMATION:

ENCLOSURE 2: XCALIBER BALLOON RISK ANALYSIS DATA SHEET

DATE: 13 September, 2019

Balloon Mission Identification: XCalibur, Antarctica 2018/2019
Is this a Test Flight: No
Balloon Office Point of Contact: David Gregory Ph.# 757-824-2367
Scientist(s): Henric Krawczynski
Launch Site: LDB Launch Site, Mcmurdo Antarctica
Latitude (deg.) = 77 S Longitude (deg.) = 167 E
Planned Launch Date: December 2018
Duration of Launch Window: Through Jan 20 2018

Payload/Balloon Characteristics

Gross Inflation Weight (lbs.): 11044
Stress Index: 1770
Suspended Payload Weight (lbs.): 6000
Payload Size (LxWxH) (ft.): 12.5 X 21.5 X 21.5 (FEET) *add 8' to height to include rotator and suspension. **Assumes worst case Telescope UNSTOWED @ 45 elevation
If cylinder – Diameter & Height (ft.): ____
Balloon Type: Zero-Pressure X Super Pressure ____
Balloon Volume (mcf.): W39.57
Balloon Weight (lbs.): 4040

Planned Flight Description:

Planned Duration of Balloon Flight (Hours/Days): >55 days
Balloon Launch and Ascent (Day – Night): Day
Balloon Float (Day – Night): Not expected to proceed past an Antarctic sunset
Float Time: (Max.) >55 day (Min.) 12 days
Float Direction (East-West-Turnaround): ___ Generally Westward
Balloon/Payload Descent and Impact (Day – Night): Day
* For LDB and ULDB: N/A
1 – Sigma Latitude Variation (Degrees): 77S +/- 10 (will not leave continent)
Estimated Float Winds (Vel.-knots): Max. = ____ Min. = ____
Mean = 29 from east 1 Sigma Variation = 11.1

Is this the first flight of a new balloon system? Yes _ No X If yes, please attach a theoretical reliability study.

SPECIAL REQUIREMENTS AND OTHER PERTINENT INFORMATION:

ENCLOSURE 3: BLAST BALLOON RISK ANALYSIS DATA SHEET

DATE: 13 September, 2019

Balloon Mission Identification: BLAST, Antarctica 2018/2019
Is this a Test Flight: No
Balloon Office Point of Contact: David Gregory Ph.# 757-824-2367
Scientist(s): Mark Devlin
Launch Site: LDB Launch Site, Mcmurdo Antarctica
Latitude (deg.) = 77 S Longitude (deg.) = 167 E
Planned Launch Date: December 2018
Duration of Launch Window: Through Jan 20 2018

Payload/Balloon Characteristics

Gross Inflation Weight (lbs.): 13206
Stress Index: 1367
Suspended Payload Weight (lbs.): 6910
Payload Size (LxWxH) (ft.): 25.5 X 15.7 X 25 (FEET)
If cylinder – Diameter & Height (ft.): ____
Balloon Type: Zero-Pressure X Super Pressure ____
Balloon Volume (mcf.): 34.43-3H-P
Balloon Weight (lbs.): 5096

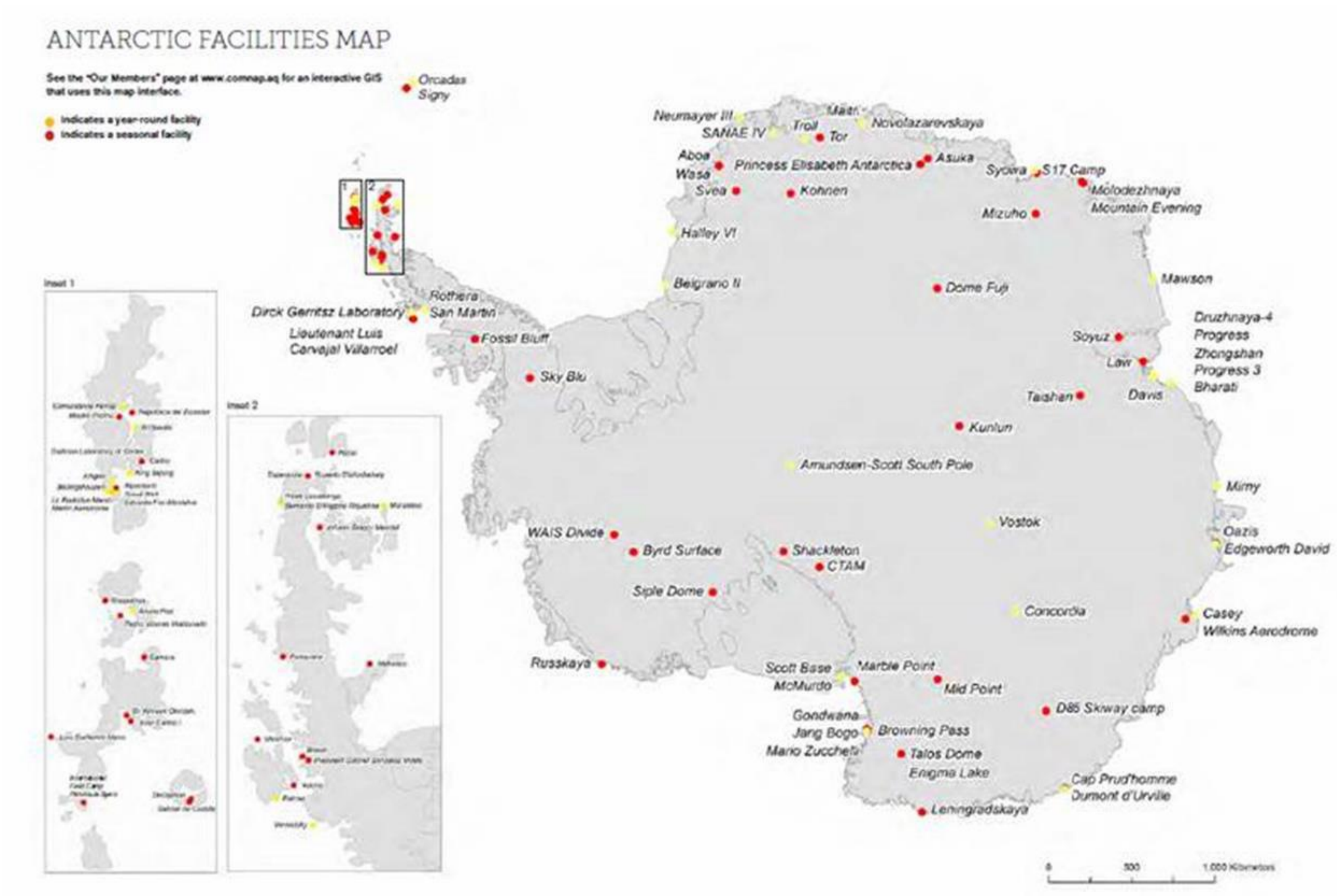
Planned Flight Description:

Planned Duration of Balloon Flight (Hours/Days): >28 days
Balloon Launch and Ascent (Day – Night): Day
Balloon Float (Day – Night): Not expected to proceed past an Antarctic sunset
Float Time: (Max.) >28 day (Min.) 10 days
Float Direction (East-West-Turnaround): ___ Generally Westward
Balloon/Payload Descent and Impact (Day – Night): Day
* For LDB and ULDB: N/A
1 – Sigma Latitude Variation (Degrees): 77S +/- 10 (will not leave continent)
Estimated Float Winds (Vel.-knots): Max. = ____ Min. = ____
Mean = 29 from east 1 Sigma Variation = 11.1

Is this the first flight of a new balloon system? Yes _ No X If yes, please attach a theoretical reliability study.

SPECIAL REQUIREMENTS AND OTHER PERTINENT INFORMATION:

ENCLOSURE 4: COMNAP ANTARCTIC FACILITIES MAP



ENCLOSURE 5: CURRENT BASIC BALLOON RISK MODEL PROGRAM, LETHAL AREA ALGORITHMS

1a) Lethal area of the balloon is calculated using balloon weight, not volume. **This change was made in 2000 based on a study by R. James Lanzi to determine the most credible value for balloon lethal area or its "footprint" on impact. It is rooted in reducing kinetic energy to an acceptable level at impact. It was decided to use the mean of the high and low bound for lethal area (.3 + .059/2)**

Balloon: $AL_{BL} = (.18)\,(W)$

where

W = balloon weight (lbs)

1b) The previous method used to calculate balloon lethal area was based on the weight and volume of the balloon. The equations are as follows:

```
BAL1 = 2.5*(SQRT(BALWT))
BAL2 = 55.0*(BALVOL**(1./3.))
BALAL = (BAL1+BAL2)/2.0
```

where

BAL1 = Balloon Dimension #1
BAL2 = Balloon Dimension #2
BALWT = Balloon Weight (lbs)
BALAL = Balloon Lethal Area

2) Lethal area of the payload has increased also with the inclusion of a 'sweepout' buffer recommended by an independent survey. This adds 5' to one dimension (length) to account for the angular descent with respect to the average height of a man. **Officially 5' as of fall 2007.**

Payload: $AL_{PL} = (L + 2 + 5)\,(W + 2)$

where

L = length (ft)
W = width (ft) or diameter (ft)
The value of 2 equates to a 1' buffer around all sides of the impacting face.
The value of 5 equates to a 5' buffer for 'sweepout'.

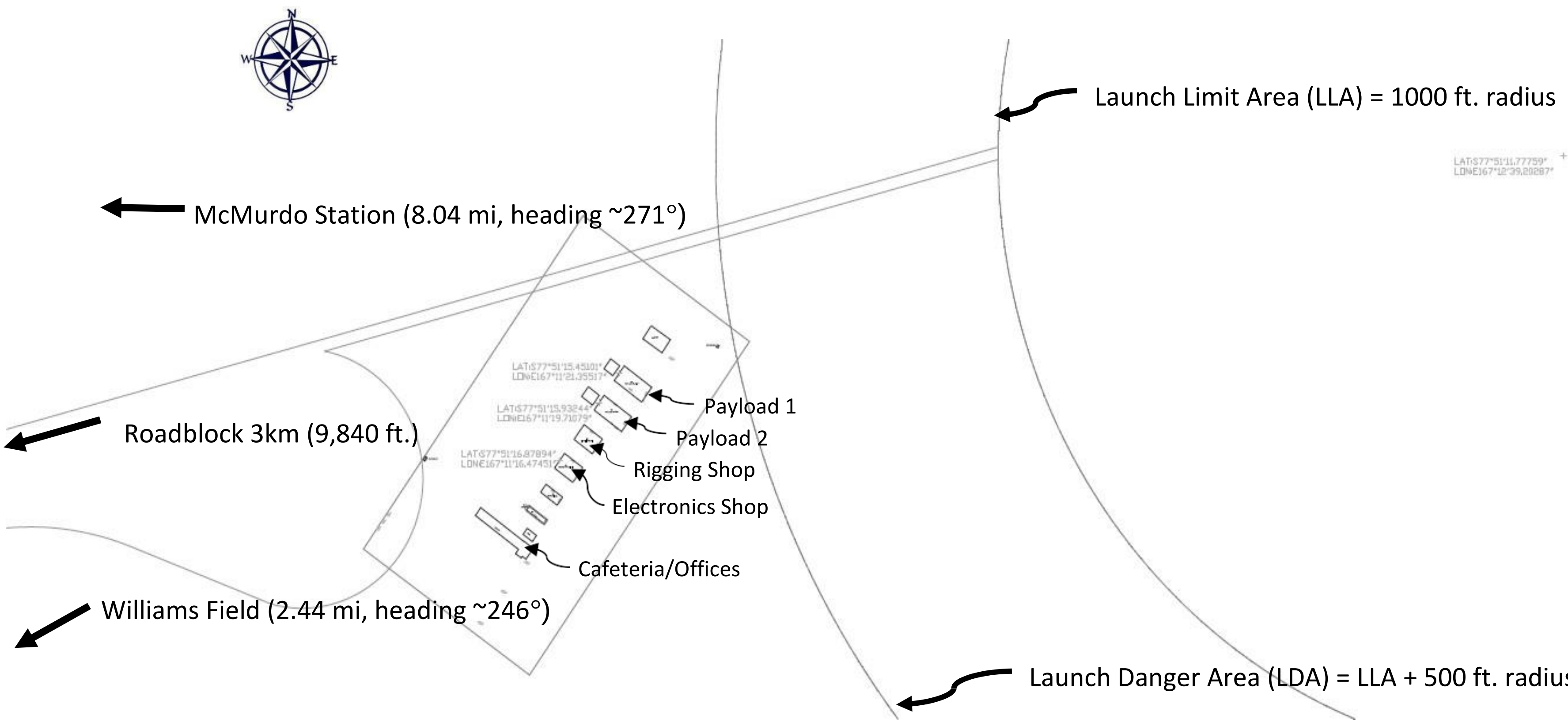
We do calculate lethal area for both the base and face of the payload and use the larger of the two areas. The sweepout buffer is added only to the length dimension. If width is still greater than length, then width is used in lethal area calculation for payload face.

For example:

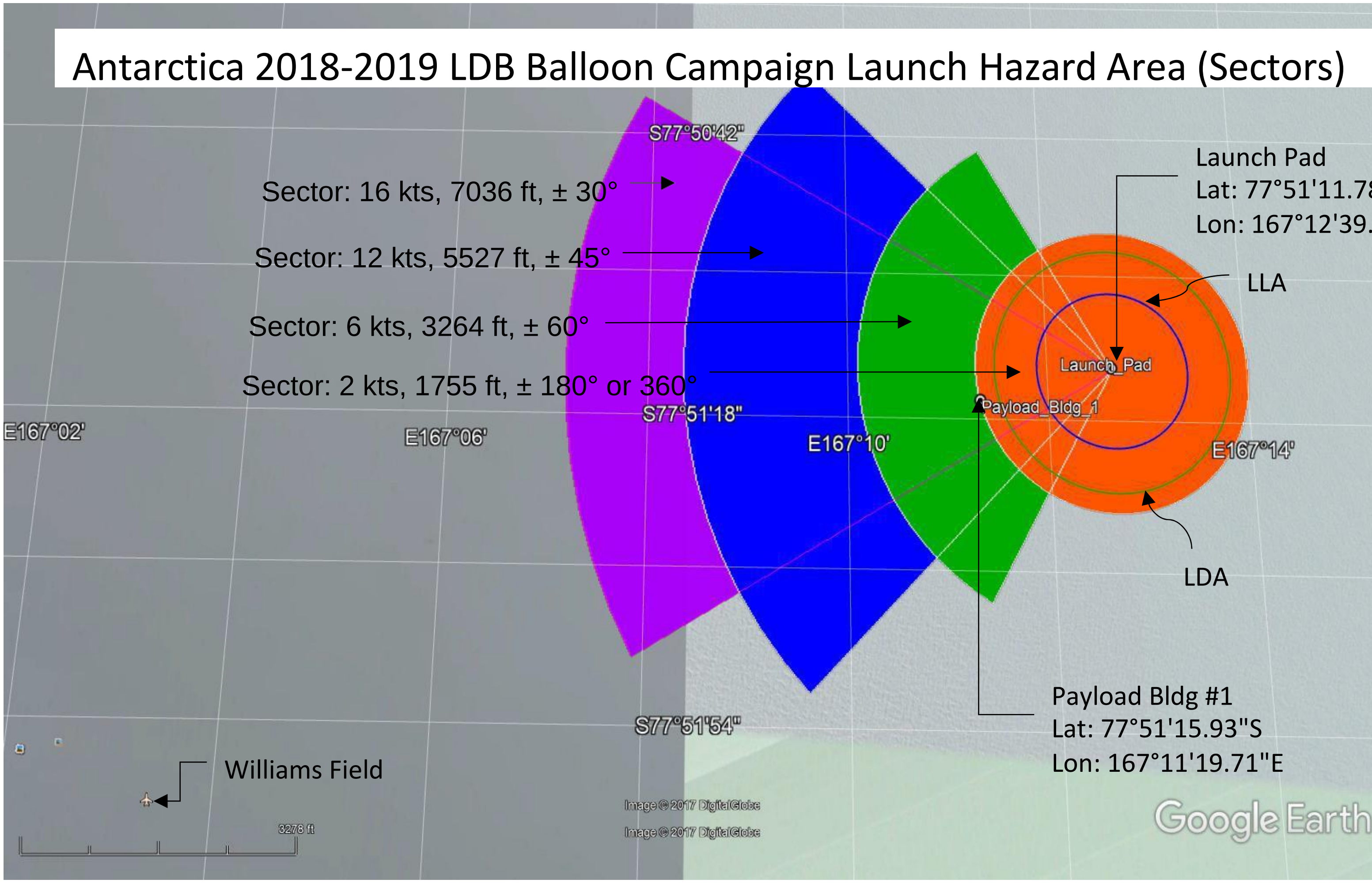
A) Payload dimensions of 10' x 12' x 6' → L = 10 + 2 + 5 = 17
W = 12 + 2 = 14
H = 6 + 2 = 8
ALPLB = 17 x 14 = 238.00
ALPLF = 17 x 8 = 136.00
Lethal area used = 238.00 sq. ft.

ENCLOSURE 6: LAUNCH LIMIT AREA AND LAUNCH DANGER AREA

Antarctica 2017-2018 LDB Balloon Campaign Launch Site Layout



ENCLOSURE 7: LAUNCH HAZARD AREA SECTORS



APPENDIX A: HAZARDS ANALYSIS REPORTS

Hazard Analysis Report

HAZARD REPORT NUMBER Balloon HR-5

PROJECT Balloon ***AUTHOR*** Maxfield/Ball

ID 228 ***LAST MODIFIED*** 06/11/18

HAZARDOUS SUBSYSTEM/OPERATION
Balloon Launch Operations

HAZARD DESCRIPTOR
Mechanical Failure of Flight Train

HAZARD DESCRIPTION
Personnel injured &/or property damaged by failure of Flight Train & subsequent whip action.

HAZARD CAUSE
1. Normal loading from balloon lift exceeds Flight Train strength. 2. Higher than normal drag from extreme wind loading exceeds Flight Train strength.

HAZARD EFFECTS
Death, Injury or Property Damage

HAZARD CONTROLS
1.1. Documented flight train engineering certification has a 10g vertical and 5g at 45 degree strength requirement which far exceeds any possible load that could be encountered during inflation. The very high strength requirements are necessitated by forces encountered at the end of the flight during parachute opening.
1.2. The LECC process includes mechanical pull tests in addition to engineering analysis and is conducted at the beginning of each campaign.
2.1. Documented LECC (launch equipment certification) process insures all launch equipment including the spool assembly and launch vehicle can withstand forces exerted at the maximum planned gross inflation including forces that may be induced by a 15 knot wind from behind the fully inflated balloon bubble.
2.2. CSBF meteorological forecasts are used to insure that winds remain within acceptable levels.
2.3. Should excessive winds be encountered, helium valves at the top of the balloon are opened causing the balloon to lose lift and deflate.
2.4 Implementation of a pre-launch danger area (PLDA) about equipment limiting access to potential hazard.

CONTROLS VERIFICATION
1.1.1. Engineering analysis is documented in the flight train certification procedure.
1.2.1. Engineering analysis and pull testing of the launch and spool vehicle assemblies is carried out and documented at the beginning of each campaign as part of the LECC.
2.1.1. LECC process is documented at the beginning of each campaign.
2.2.1. Meteorological briefings are carried out prior to the start of each operation.
2.3.1. Crew Chiefs are updated after the operation begins as required.
2.3.2. Helium valve opening in the event of unexpected extreme winds is standard operating procedure.
2.4. GSO/MRSO ensures implementation of PLDA limiting personnel in controlled area, according to the approved GSP.

VERIFICATION STATUS
1 1.1. CLOSED. 1.2.1 CLOSED. 2.1.1. CLOSED. 2.2.1. CLOSED. 2.3.1. CLOSED. 2.3.2. CLOSED. 2.4 CLOSED

INITIAL RISK SEVERITY	*I*	*INTERIM RISK SEVERITY*	*I*
INITIAL MISHAP PROBABILITY	*C*	*INTERIM MISHAP PROBABILITY*	*D*
INITIAL RISK ASSESSMENT CODE	*1*	*INTERIM RISK ASSESSMENT CODE*	*2*

FINAL RISK SEVERITY	*I*
FINAL MISHAP PROBABILITY	*E*
FINAL RISK ASSESSMENT CODE	*3*

NOTES/COMMENTS
Reviewed 06/11/18 L.Wiles/Code 803, Disposition: Added discussion of PLDA as hazard mitigation.

Hazard Analysis Report

HAZARD REPORT NUMBER Balloon HR-14

PROJECT Balloon ***AUTHOR*** Moskios/Maxfield/Ball

ID 237 ***LAST MODIFIED*** 9/8/2010

HAZARDOUS SUBSYSTEM/OPERATION

Balloon Launch Operations

HAZARD DESCRIPTOR

Insufficient Lift in Balloon System

HAZARD DESCRIPTION

Helium valve not closed at inflation start; helium escapes & lift is insufficient for launch.

HAZARD CAUSE

1. Malfunction of helium valve. 2. Helium valve “close” command not sent following flight line checkout. 3. Unauthorized personnel within PLDA.

HAZARD EFFECTS

Death, Injury or Property Damage

HAZARD CONTROLS

1.1. Helium valve design approved by NASA/WFF Applied Engineering Tech. Directorate (AETD).
1.2. Helium valve parts produced from a documented manufacturing drawing package.
1.3. Helium valves are bench checked prior to putting them into service.
1.4. Following installation in the balloon during the launch operations, helium valves undergo a functional check through all parachute and balloon wiring.
2.1. The final step in the valve test is a checklist item indicating concurrence that the valves are closed.
2.2. Helium valves equipped with limit switches which toggle “open” or “closed” status to ground station software; when helium valve limit switch is in “open” status, text on ground station flight data monitors turns red. Valve closure is confirmed visually and through software.
3.1. Implementation of a pre-launch danger area (PLDA) about equipment limiting access to potential hazard.

CONTROLS VERIFICATION

1.1.1. NASA/WFF/AETD engineering acceptance.
1.2.1. Manufacturing standards.
1.3.1. Standard CSBF procedure.
1.3.2. Recurrent training of launch crew members on operational procedures.
1.3.3. Colored sticker system on valves indicates that they have been properly bench checked.
1.4.1. Flight line helium valve installation is part of documented Balloon Technician career ladder process.
1.4.2. Electrical functional checks on the flight line are part of CSBF Electronics Technician OJT training program.
2.1.1. Standard CSBF procedure.
2.1.2. Recurrent training of launch crew members on operational procedures.
2.2.1. Standard CSBF design parameter.
2.2.2. Recurrent training of launch crew members on operational procedures.
3.1. GSO/MRSO ensures implementation of PLDA limiting personnel in controlled area, according to the approved GSP.

VERIFICATION STATUS

1.1.1. CLOSED. 1.2.1. CLOSED. 1.3.1. CLOSED. 1.3.2. CLOSED. 1.3.3. CLOSED. 1.4.1. CLOSED. 1.4.2. CLOSED. 2.1.1. CLOSED. 2.1.2. CLOSED. 2.2.1. CLOSED. 2.2.2. CLOSED. 3.1 CLOSED.

INITIAL RISK SEVERITY I ***INTERIM RISK SEVERITY*** I ***INITIAL MISHAP PROBABILITY*** C ***INTERIM MISHAP PROBABILITY*** D ***INITIAL RISK ASSESSMENT CODE*** 1 ***INTERIM RISK ASSESSMENT CODE*** 2

FINAL RISK SEVERITY I
FINAL MISHAP PROBABILITY E
FINAL RISK ASSESSMENT CODE 3

NOTES/COMMENTS

Reviewed 7/16/18 T.Moskios/Code 803 Disposition: Added 3.1, 3.1.1, and verification status

Hazard Analysis Report

HAZARD REPORT NUMBER Balloon HR-17 Rev-A

PROJECT Balloon ***AUTHOR*** Moskios/Green/J. Marsh/Salter

ID A1B ***LAST MODIFIED*** 7/23/2018

HAZARDOUS SUBSYSTEM/OPERATION
Balloon Launch Operations

HAZARD DESCRIPTOR
Collar fails to deploy resulting in launch abort.

HAZARD DESCRIPTION
The balloon collar fails to deploy during a launch operation, and then the balloon launch will be aborted. Launch abort will be passive (where helium is released via valve(s) on the balloon), or active (the balloon termination system is activated). The risks of passive and active aborts are addressed in HR-39 . If launch occurred and the collar did not deploy, the balloon flight will be terminated using standard procedures. The risk due to balloon termination is addressed in HR-38. If the balloon mission is not terminated, and the collar is still on the balloon, then the balloon will burst at approximately 40,000 ft. The risk due to a burst balloon during the ascent or float phases is addressed in HR-29. The electronics portion of the collar release system is the ICEP (Interim Collar Electronics Package) or the ACER (Advanced Collar Electronics Radio)

HAZARD CAUSE
1. Visual indication of collar release failed; and,
2. Ordnance subsystem failure; or,
3. ACER and/or electrical ground system failure; or,
4. Mechanical system failure.

HAZARD EFFECTS
Property damage or loss of launch opportunity.

HAZARD CONTROLS
1.1 RSO/CM call for launch abort if no visual confirmation of collar release.

2.1. Redundant EEDs present in the release mechanism.
2.2. Lot qualification testing of EEDs performed by manufacturer.
2.3. EEDs bridgewire resistance checked as part of flight readiness .
2.4. EED test equipment calibrated at WFF.
2.5. Certified ordnance handlers perform EED installation and connection in accordance with standard procedure.

3.1. Firing circuitry is compliant with RSM2002C in terms of grounding, shielding, and bleed resistors.
3.2. ACER design underwent qualification testing. Each unit undergoes acceptance testing. Redundant electronics package.
3.3 System undergoes testing prior to flight. Redundant antenna systems.
3.4. Flight line end-to-end functional test of system performed during installation of collar (minutes before the system is activated).

4.1. Collars are constructed from standard templates to insure proper functionality.
4.2. Lacing rings are chrome plated to reduce friction.
4.3. Lacing hardware and installation procedure is SOP and part of Crew Chief training program.
4.4. Soft Collar is marked with arrows so it can't be installed upside down.

CONTROLS VERIFICATION
1.1.1. As documented in current balloon FSP.

2.1.1. New ACER AETD design, as shown in dwg # 2287044. For ICEP, see the drawing on p. 15 of the Electronics Package NASA Review Rev 2, dated 8/9/2017.
2.2.1. PSEMC 6801 qualified per Mil-Std-1576 in regard to section 5, 1amp/1watt no fire.
2.3.1. As required in procedure ES-100-20-P (for both ICEP and ACER), and performed by ordnance certified CSBF technician, who is certified in accordance with GPR 8715.11..
2.4.1. Calibration verified by inspection by OSS in the field, as documented in the OSS checklist.

2.5.1. Ordnance handlers certified in accordance with GPR 8715.11, which is verified by OSS.
2.5.2 EED connection and installation in accordance with procedure ES100-20-P.

3.1.1. Wallops Ground Safety Group review & approval of EEDs and firing circuit, as shown in dwg # 2287042.
3.2.1. As defined in the ACER Critical Design Review package.
3.3.1. Redundancy shown in dwg # 2287042. For ICEP, see the drawing on p. 15 of the Electronics Package NASA Review Rev 2, dated 8/9/2017. Flight line testing performed per ACER-PROC-008 (for ICEP EL-531-10-P).
3.4.1. Flight line end-to-end procedure performed in accordance with ACER-PROC-008 (for ICEP EL-531-10-P).

4.1.1. Standard CSBF design, as shown in dwg #OF-400-171-1-SC.
4.2.1. Standard CSBF design, as shown in dwg #OF-400-171-1-SC.
4.3.1. Proper Collar installation is part of documented in procedure # OF-328-05-P.
4.4.1. Campaign Manager must approve collar installation and sign off on the configuration after installation on the balloon immediately prior to launch per procedure OF-322-10—C.

VERIFICATION STATUS

1 1.1. CLOSED. 2.1.1. CLOSED. 2.2.1. CLOSED. 2.3.1. CLOSED. 2.4.1. CLOSED. 2.5.1. CLOSED. 3.1.1. CLOSED. 3.2.1. CLOSED. 3.3.1. CLOSED. 3.4.1. CLOSED. 4.1.1. CLOSED. 4.2.1. CLOSED. 4.3.1. CLOSED. 4.4.1. CLOSED.

INITIAL RISK SEVERITY	II	***INTERIM RISK SEVERITY***	II
INITIAL MISHAP PROBABILITY	C	***INTERIM MISHAP PROBABILITY***	D
INITIAL RISK ASSESSMENT CODE	2	***INTERIM RISK ASSESSMENT CODE***	3

FINAL RISK SEVERITY	II
FINAL MISHAP PROBABILITY	E
FINAL RISK ASSESSMENT CODE	3

NOTES/COMMENTS: This supersedes HR-17.

Hazard Analysis Report

HAZARD REPORT NUMBER Balloon HR-18

PROJECT Balloon **AUTHOR** Maxfield/Ball

ID 241 **LAST MODIFIED** 9/17/2010

HAZARDOUS SUBSYSTEM/OPERATION
Balloon Launch Operations

HAZARD DESCRIPTOR
Crew Member Falls Off Launch Vehicle (LV)

HAZARD DESCRIPTION
Abrupt maneuver of Launch Vehicle Ejects Crew Member

HAZARD CAUSE
1. Unpredictable/unexpected accelerations, decelerations, and/or turns of Launch Vehicle.
2. Launch vehicle is pulled up on two wheels or overturned by excessive side loading in extreme wind conditions

HAZARD EFFECTS
Death, Injury or Property Damage

HAZARD CONTROLS
1.1. Secure seats with restraining harness provided for electronic technicians on LV.
1.2. High strength guard rails mounted on platform provide fall protection for Crew Chief and mechanical technicians.
1.3. Secure seat with seat belt provided for driver.
1.4. Crew trained to ensure restraints are fastened before first motion of LV.
1.5. All LV staff members use a central intercom headset for constant communications and awareness of instructions given to the driver.
2.1. All launch vehicles are either equipped with and extremely wide front wheel base or equipped with outriggers to prevent the vehicle from overturning or being pulled up on two wheels.
2.2. Balloon is terminated if there is excessive side loading during a launch.

CONTROLS VERIFICATION
1.1.1. Standard LV design.
1.2.1. Standard LV design.
1.3.1. Standard LV design.
1.4.1. Recurrent training of launch crew members on operational procedures.
1.5.1. Standard CSBF procedure.
1.5.2. Recurrent training of launch crew members on operational procedures.
1.5.3. A communication check is done with all crew members on the vehicle prior to balloon release.
2.1.1. CSBF mechanical engineers supervise the design and manufacture of permanent launch vehicles and design the outriggers for leased cranes to insure vehicle stability during launch.
2.2.1. Standard CSBF procedure.
2.2.2. Recurrent training of launch crew members on operational procedures.
2.2.3. Central intercom headset for constant communications and awareness.

VERIFICATION STATUS
1.1.1. CLOSED. 1.2.1. CLOSED. 1.3.1. CLOSED. 1.4.1. CLOSED. 1.5.1. CLOSED. 1.5.2. CLOSED. 1.5.3. CLOSED. 2.1.1. CLOSED. 2.2.1. CLOSED. 2.2.2. CLOSED. 2.2.3. CLOSED.

INITIAL RISK SEVERITY I
INITIAL MISHAP PROBABILITY C
INITIAL RISK ASSESSMENT CODE 1

INTERIM RISK SEVERITY I
INTERIM MISHAP PROBABILITY D
INTERIM RISK ASSESSMENT CODE 2

FINAL RISK SEVERITY I
FINAL MISHAP PROBABILITY E
FINAL RISK ASSESSMENT CODE 3

NOTES/COMMENTS
Reviewed 06/11/18 L.Wiles/Code 803 Disposition: No Change

Hazard Analysis Report

HAZARD REPORT NUMBER Balloon HR-19

PROJECT Balloon ***AUTHOR*** Maxfield/Ball/Moskios/Salter

ID 242 ***LAST MODIFIED*** 7/20/2018

HAZARDOUS SUBSYSTEM/OPERATION

Balloon Launch Operations

HAZARD DESCRIPTOR

Crew member injured during launch operation.

HAZARD DESCRIPTION

Crew member(s) are injured during one of the phases of a balloon launch prior to actual balloon release: 1) release from spool; 2) prior to release from the LV; and, 3) immediately after balloon release from the launch vehicle.

HAZARD CAUSE

1. Crew member(s) struck by spool.
2. Cables of flight train become entangled in LV structure.
3. Erroneous LV maneuver(s) cause balloon train or payload to impact the LV.
4. Abrupt wind shift at the time of balloon release.

HAZARD EFFECTS

Death, Injury or Property Damage

HAZARD CONTROLS

1.1. Spool release performed by specifically authorized personnel in accordance with crew chief approval.
2.1. Launch equipment certification process ensures extraneous appendages are removed from LV, and that the flight train is correctly rigged.
3.1 LV drivers are trained to avoid the flight train, so as not to become entangled.
4.1. Professional meteorologist closely monitors wind conditions and communicates status to Crew Chief and Campaign Manager prior to launch.
4.2. Crew Chief training includes wind gust response.

CONTROLS VERIFICATION

1.1.1. Spool release technician trained per OJT and documented in career path training (OF-621-01).
1.1.2. Spool release in accordance with crew chief direction, per OF-621-01.
2.1.1 LV and train equipment certified per OF-603-00.
2.2.1. Flight train is rigged per checklist, OF-336-00-C.
2.2.2. LV checked out per launch director's checklist, OF-322-10-C.
3.1.1. Driver training per rigging career path, OF-621-01.
4.1.1. Per prelaunch director's checklist, OF-322-10-C
4.2.1. Crew Chief training per 820-FORM-2017-2.

VERIFICATION STATUS

1.1.1. CLOSED. 1.1.2. CLOSED. 2.2.1. CLOSED. 2.2.2. CLOSED. 3.1.1. CLOSED. 4.1.1. CLOSED. 4.1.2. CLOSED

INITIAL RISK SEVERITY I ***INTERIM RISK SEVERITY*** I
INITIAL MISHAP PROBABILITY C ***INTERIM MISHAP PROBABILITY*** D
INITIAL RISK ASSESSMENT CODE 2 ***INTERIM RISK ASSESSMENT CODE*** 2

FINAL RISK SEVERITY I
FINAL MISHAP PROBABILITY E
FINAL RISK ASSESSMENT CODE 3

NOTES/COMMENTS Reviewed 7/20/18, T.Moskios, Disposition: Procedures identified

Hazard Analysis Report

HAZARD REPORT NUMBER Balloon HR-20

PROJECT Balloon **AUTHOR** Maxfield/Ball

ID 243 **LAST MODIFIED** 9/17/2010

HAZARDOUS SUBSYSTEM/OPERATION
Balloon Launch Operations

HAZARD DESCRIPTOR
Flight Train or Payload Impacts Launch Vehicle (LV)

HAZARD DESCRIPTION
Payload &/or Flight Train pivots about suspension point and collide or strikes LV boom

HAZARD CAUSE
1. Abrupt maneuvering of the launch vehicle. 2. Sudden wind shifts during launch. 3. Premature release of the payload.

HAZARD EFFECTS
Death, Injury or Property Damage

HAZARD CONTROLS
1.1. Pre-launch Crew Briefings include potential LV paths and maneuvers.
1.2. Mechanical Technicians on LV prevent excessive payload motion by holding tag lines attached to payload.
2.1. CSBF meteorologist closely monitors low level winds before balloon layout and inflation to help Crew Chief accurately predict the best layout direction.
2.2. CSBF meteorologist relays the real-time data to the Launch Crew Chief throughout the launch operation.
3.1. The CSBF Crew Chief training and qualification program certifies a crew chief to perform payload launches through the use of both classroom and controlled balloon launches to provide the necessary experience to make this type of real time decision.

CONTROLS VERIFICATION
1.1.1. Checklist used by Launch Crew Chief for balloon launch operations.
1.1.2. OSS Verification in OSS checklist.
1.2.1. Standard CSBF procedure.
1.2.2. Proper payload control methods are part of documented Balloon Technician career path training program.
2.1.1. Surface level wind records recorded for each launch operation.
2.1.2. CSBF training and procedure.
2.2.1. Communication checks at start of launch operations.
2.2.2. CSBF training and procedure.
3.1.1. Launch Crew Chief career path training documentation in the staff employee records.

VERIFICATION STATUS
1.1.1. CLOSED. 1.1.2. CLOSED. 1.2.1. CLOSED. 1.2.2. CLOSED. 2.1.1. CLOSED. 2.1.2. CLOSED. 2.2.1. CLOSED. 2.2.2. CLOSED. 3.1.1. CLOSED

INITIAL RISK SEVERITY I
INITIAL MISHAP PROBABILITY C
INITIAL RISK ASSESSMENT CODE 1

INTERIM RISK SEVERITY I
INTERIM MISHAP PROBABILITY D
INTERIM RISK ASSESSMENT CODE 2

FINAL RISK SEVERITY I
FINAL MISHAP PROBABILITY E
FINAL RISK ASSESSMENT CODE 3

NOTES/COMMENTS

Reviewed 06/11/18 L.Wiles/Code 803 Disposition: No Change

Hazard Analysis Report

HAZARD REPORT NUMBER Balloon HR-21

PROJECT Balloon ***AUTHOR*** Maxfield/Ball

ID 244 ***LAST MODIFIED*** 9/21/2010

HAZARDOUS SUBSYSTEM/OPERATION
Balloon Launch Operations

HAZARD DESCRIPTOR
Payload Launch Head Release Mechanism Fails

HAZARD DESCRIPTION
Payload Release Mechanism fails to function when activated by Crew Chief

HAZARD CAUSE
1. Degradation of release mechanism between launch campaigns. 2. Damage to mechanism during launch preparations/operations.

HAZARD EFFECTS
Death, Injury or Property Damage

HAZARD CONTROLS
1.1. Protective cover placed on launch head when not in use to protect dust and dirt accumulation.
1.2. Storage of LV between campaigns in protective environment.
1.3. Pre-launch examination and testing of the launch head including functionality, lubrication, and release pin friction testing which exceeds any loads that can be experienced during launch.
2.1. Only the qualified Crew Chief performs this LV release function.

CONTROLS VERIFICATION
1.1.1. Standard CSBF procedure.
1.2.1. Standard CSBF procedure.
1.3.1. Pre-launch examination and testing is documented by CSBF mechanical engineer.
1.3.2. Launch head fabrication drawing package is documented to insure all launch heads are identical.
2.1.1. Proper release mechanism handling and activation is part of documented Balloon Crew Chief career path training program.

VERIFICATION STATUS
1.1.1. CLOSED. 1.2.1. CLOSED. 1.3.1. CLOSED. 1.3.2. CLOSED. 2.1.1. CLOSED.

INITIAL RISK SEVERITY I ***INTERIM RISK SEVERITY*** I ***INITIAL MISHAP PROBABILITY*** B ***INTERIM MISHAP PROBABILITY*** C ***INITIAL RISK ASSESSMENT CODE*** 1 ***INTERIM RISK ASSESSMENT CODE*** 2

FINAL RISK SEVERITY I ***FINAL MISHAP PROBABILITY*** E ***FINAL RISK ASSESSMENT CODE*** 3

NOTES/COMMENTS
Reviewed 7/16/18 T.Moskios/Code 803 Disposition: Changed risk severity to I.

Hazard Analysis Report

HAZARD REPORT NUMBER Balloon HR-22

PROJECT Balloon **AUTHOR** Maxfield/Ball

ID 245 **LAST MODIFIED** 9/21/2010

HAZARDOUS SUBSYSTEM/OPERATION
Balloon Launch Operations

HAZARD DESCRIPTOR
Balloon strikes ground and payload is damaged due to late release.

HAZARD DESCRIPTION
Crew Member Struck by Spool

HAZARD CAUSE
1. Unexpected changes in wind speed and direction during the launch operation. 2. Error in judgment by crew member.

HAZARD EFFECTS
Property Damage

HAZARD CONTROLS
1.1 The meteorologist performs surface and low level wind data collection to accurately forecast wind shifts.
1.2. The meteorologist performs real time surface and low level wind data assessments and keeps the Crew Chief advised of changes.
2.1. Crew Chief is the only crew member allowed to direct release of the payload.

CONTROLS VERIFICATION
1.1.1. The meteorologist has a defined set of parameters and low level wind soundings to perform prior to each launch.
1.2.1. Standard CSBF policy.
1.2.2. Voice communications checked and verified at start of launch operations.
2.1.1. The Crew Chief has been trained through actual mentored launches to accurately time the release of the payload from the launch vehicle.
2.1.2. CSBF career training program for Crew Chiefs insures skills are adequate to prevent this hazard.

VERIFICATION STATUS
1.1.1. CLOSED. 1.2.1. CLOSED. 1.2.2. CLOSED. 2.1.1. CLOSED. 2.1.2. CLOSED.

INITIAL RISK SEVERITY II **INTERIM RISK SEVERITY** II

INITIAL MISHAP PROBABILITY B **INTERIM MISHAP PROBABILITY** C

INITIAL RISK ASSESSMENT CODE 1 **INTERIM RISK ASSESSMENT CODE** 2

FINAL RISK SEVERITY II

FINAL MISHAP PROBABILITY D

FINAL RISK ASSESSMENT CODE 3

NOTES/COMMENTS
Reviewed 06/11/18 L.Wiles/Code 803 Disposition: No Change

Hazard Analysis Report

HAZARD REPORT NUMBER Balloon HR-23

PROJECT Balloon **AUTHOR** Maxfield/Ball

ID 246 **LAST MODIFIED** 9/21/2010

HAZARDOUS SUBSYSTEM/OPERATION
Balloon Launch Operations

HAZARD DESCRIPTOR
Launch Vehicle (LV) Motor Stalls

HAZARD DESCRIPTION
Payload not placed under balloon when directed because LV motor stalls

HAZARD CAUSE
1. Equipment failure. 2. Driver error.

HAZARD EFFECTS
Property Damage

HAZARD CONTROLS
1.1. Preventative maintenance program on all launch vehicles.
1.2. Launch Vehicle is started and checked immediately prior to balloon release from the spool.
2.1. Launch vehicle drivers are formally trained as part of the Balloon Technician career ladder.
2.2. Launch vehicle driving tests are performed at the beginning of each campaign.

CONTROLS VERIFICATION
1.1.1. Documented maintenance program for all permanent launch vehicles.
1.2.1. Standard CSBF launch operations procedure.
2.1.1. Documented driver training program.
2.2.1. Documented driver certification program.

VERIFICATION STATUS
1.1.1. CLOSED. 1.2.1. CLOSED. 2.1.1. CLOSED. 2.2.1. CLOSED.

INITIAL RISK SEVERITY II **INTERIM RISK SEVERITY** II

INITIAL MISHAP PROBABILITY B **INTERIM MISHAP PROBABILITY** C

INITIAL RISK ASSESSMENT CODE 1 **INTERIM RISK ASSESSMENT CODE** 2

FINAL RISK SEVERITY II

FINAL MISHAP PROBABILITY E

FINAL RISK ASSESSMENT CODE 3

NOTES/COMMENTS
Reviewed 06/11/18 K. Cranor/Code 803 Disposition: No Change

Hazard Analysis Report

HAZARD REPORT NUMBER Balloon HR-24 ***PROJECT*** Balloon ***AUTHOR*** Maxfield/Ball ***ID*** 247

LAST MODIFIED 9/21/2010 ***HAZARDOUS SUBSYSTEM/OPERATION*** Balloon Launch Operations

HAZARD DESCRIPTOR

Personnel/Equipment Run Over by LV During or After Launch

HAZARD DESCRIPTION

Non-participating staff, scientists, or observers are struck by moving launch vehicle or balloon

HAZARD CAUSE

1. Non-essential personnel in the hazard area. 2. Improper spectator control. 3. Launch Vehicle exits operations area.

HAZARD EFFECTS

Death, Injury or Property Damage

HAZARD CONTROLS

1.1. Clearing Operations Area of non-essential personnel is part of the Launch Countdown.
1.2. Operations Safety Supervisor (OSS) verifies area has been cleared.
2.1. Operations area is surrounded by buffer of sufficient margin to protect spectators outside that perimeter.
2.2. Perimeter check for out-of-place/unauthorized spectators is performed before Launch Countdown begins.
2.3. Road blocks are set up and manned by assigned personnel, or law officers, to prevent vehicles or personnel from entering hazardous areas.
3.1. The Operations Area, specific to each launch site, is defined in the pre-mission briefing.
3.2. Launch Vehicle (LV) drivers familiarize themselves with Ops Area limits before launch ops begin.
3.3. If the launch vehicle is in danger of running out of the area, the flight is aborted.
3.4. Hazards, restrictions, ops area and plans for crowd control are briefed in the Haz-Op briefing, by the OSS.

CONTROLS VERIFICATION

1.1.1. Standard Operations Procedure (SOP).
1.2.1. OSS verification recorded in OSS checklist.
2.1.1. Engineering and operational analysis used to establish parameters for the launch operations area, as documented in FSP.
2.1.2. Launch operations area and buffer approved by WFF Ground Safety Office and documented in the GSP.
2.2.1. SOP.
2.2.2. OSS verification recorded in OSS checklist.
2.3.1. SOP.
2.3.2. OSS verification recorded in OSS checklist..
3.1.1. Established outline for pre-operational safety briefing to ensure all safety aspects are covered.
3.2.1. SOP.
3.3.1. SOP.
3.3.2. Proper abort procedure is part of documented Balloon Technician career path training program.
3.3.3. Recurrent training of launch crew members on abort procedures.
3.3.4. Crew Chief calls for abort if launch criteria are exceeded.
3.3.5. Campaign Manager calls for abort if Crew Chief fails to when needed.
3.3.6. OSS calls for launch abort CM and CC fail to do so when needed.
3.4.1. SOP.
3.4.2. Established outline for pre-operational safety briefing ensures all safety aspects are covered.

VERIFICATION STATUS

1.1.1 CLOSED. 1.2.1. CLOSED. 2.1.1. CLOSED. 2.1.2. CLOSED. 2.2.1. CLOSED. 2.2.2. CLOSED. 2.3.1. CLOSED. 2.3.2. CLOSED. 3.1.1. CLOSED. 3.2.1. CLOSED. 3.3.1. CLOSED. 3.3.2. CLOSED. 3.3.3. CLOSED. 3.3.4. CLOSED. 3.3.5. CLOSED. 3.3.6. CLOSED. 3.4.1. CLOSED. 3.4.2. CLOSED.

INITIAL RISK SEVERITY I ***INTERIM RISK SEVERITY*** I

INITIAL MISHAP PROBABILITY B ***INTERIM MISHAP PROBABILITY*** C ***INITIAL RISK ASSESSMENT CODE*** 1 ***INTERIM RISK ASSESSMENT CODE*** 2

FINAL RISK SEVERITY I

FINAL MISHAP PROBABILITY E

FINAL RISK ASSESSMENT CODE 3

NOTES/COMMENTS: Reviewed 06/11/18 L.Wiles/Code 803 Disposition: No Change

Hazard Analysis Report

HAZARD REPORT NUMBER Balloon HR-29

PROJECT Balloon ***AUTHOR*** Moskios/Salter/Maxfield/Ball

ID ***LAST MODIFIED*** 7/20/2018

HAZARDOUS SUBSYSTEM/OPERATION

Balloon Flight Operations

HAZARD DESCRIPTOR

Balloon burst during ascent or float phases

HAZARD DESCRIPTION

Balloon envelope fails. Payload and balloon carcass descend in an unplanned fashion.

HAZARD CAUSE

1. Balloon failure due to manufacturing or material defects. 2. Balloon damaged during inflation or launch. 3. The risk of a burst balloon during a balloon mission is acceptable.

HAZARD EFFECTS

Death, injury, property damage, danger to commercial and general aviation.

HAZARD CONTROLS

1.1 Documented material and production quality control and quality assurance program including balloon film acceptance testing and independent Quality Assurance surveillance by CSBF technicians at the balloon plant.
2.1 A balloon that develops a hole during inflation and launch has a very clear shape anomaly as it is ingesting air. Prior to launch, balloons seen to be ingesting air are aborted prior to payload release. A balloon exhibiting this characteristic during ascent is terminated at the earliest opportunity in a controlled and safe manner.
3.1 WFF performs Risk Analysis review for ascent, float, and termination phases of each flight to insure calculated Casualty Expectation figures match NASA safety criteria during planned and unplanned terminations.

CONTROLS VERIFICATION

1.1.1 Formal monthly and semi-annual quality reviews conducted with balloon manufacturer by NASA management and CSBF Balloon Quality Engineer, QA-150-R, “Balloon Reliability and Quality Assurance Plan.”
2.1.1 Documented procedure for launch aborts and planned terminations OF-690-00-P.
3.1.1. Balloon Risk Analysis and Flight Safety Plan is reviewed and approved, and then presented in the formal Flight Readiness Meeting to insure compliance with the flight rules.

VERIFICATION STATUS

1.1.1 CLOSED 2.1.1 CLOSED. 3.1.1 CLOSED

INITIAL RISK SEVERITY I

INITIAL MISHAP PROBABILITY C

INITIAL RISK ASSESSMENT CODE 1

INTERIM RISK SEVERITY I

INTERIM MISHAP PROBABILITY D

INTERIM RISK ASSESSMENT CODE 2

FINAL RISK SEVERITY I

FINAL MISHAP PROBABILITY E

FINAL RISK ASSESSMENT CODE 3

NOTES/COMMENTS

Reviewed 07/20/18 T.Moskios/Code 803 Disposition: Added documents

Hazard Analysis Report

HAZARD REPORT NUMBER Balloon HR-30

PROJECT Balloon ***AUTHOR*** Moskios/Salter/Maxfield/Ball

ID ***LAST MODIFIED*** 7/24/2018

HAZARDOUS SUBSYSTEM/OPERATION
Balloon Flight Operations

HAZARD DESCRIPTOR
Terminate system fails leading to a derelict balloon

HAZARD DESCRIPTION
UTP, RFU, EEDs, terminate fitting, or ground or aircraft based command system fails in a manner that eliminates the ability to terminate the flight according to SOP.

HAZARD CAUSE
1. Ordnance system failure.
2. Electronics system failure.
3. Mechanical failure of terminate system to separate.
4. Failure of ground and aircraft Line-of-sight uplink command system failure and OTH command paths.

HAZARD EFFECTS
Death, injury, property damage, danger to commercial and general aviation.

HAZARD CONTROLS
1.1 BTS electronics meets NASA/WFF circuit requirements, including redundant EEDs.
1.2 Lot qualification performed by the manufacturer.
1.3 EEDs checked as part of the preflight readiness.
1.4 EED test equipment calibrated at WFF.
1.5 Certified ordnance handlers perform the EEDs connection and installation in accordance with standard procedure.
2.1 Redundant command paths.
2.2 Acceptance testing performed upon UTP and RFU electronics systems.
2.3 Proper assembly of BTS electronics.
2.4 Flightline checkout of the termination system electronics.
2.5 If the electronics fails to operate the BTS, a 70 kft aneroid switch will activate the BTS on the mission downleg, but not on every mission.
3.1 Approved mechanical design.
3.2 Mechanical portion of the BTS installed correctly.
3.3 Proven reliability.
3.4 Terminate fittings undergo pull test.
4.1 LOS Transmitters and OTH command paths both ground and air systems checked out prior to flight.
4.2 Redundant transmission systems including both LOS and OTH transmission modes.

CONTROLS VERIFICATION
1.1.1. Ordnance drawings available in the GS RAR, RFU and Connections.
1.1.2. Ordnance drawings available in the GS RAR, UTP Relays, Arm-Fire, Aneroid Switch Circuit.
1.1.3 MIP Terminate PCB drawing available in the GS RAR.
1.2.1 PSEMC 6803 qualified per Mil-Std-1576 in regard to section 5, 1amp/1watt no fire.
1.3.1 As required in procedure ES-100-20-P.
1.3.2 Performed by ordnance certified CSBF technician, certified in accordance with GPR 8715.11.
1.4.1 As required in procedure ES-100-20-P.
1.4.2 Verified by inspection by OSS in the field, as documented in the OSS checklist.
1.5.1 As required in procedure ES-100-20-P.
1.5.2 Performed by ordnance certified CSBF technician, certified in accordance with GPR 8715.11.
2.1.1 Documented in the Balloon System FTSR, 820-FTSR-2011-1.
2.2.1 Environmental testing per EC-300-12, EC-300-11, and flight line testing EC-700 series
2.3.1 Assembled in accordance with EC-300-04-P.
2.3.2 Ordnance drawings available in the GS RAR, RFU and Connections.
2.3.3 Ordnance drawings available in the GS RAR, UTP Relays, Arm-Fire, Aneroid Switch Circuit.
2.3.4 MIP Terminate PCB drawing available in the GS RAR.
2.4.1 In accordance with EC-700 series.
2.5.1 In accordance with ordnance drawings available in the GS RAR.
2.6.1 According to the Balloon System FTSR, 820-FTSR-2011-1.
3.1.1 Approved drawing OF-317-10-C
3.2.1 Fitting Loop Assembly Procedure, OF-106-00-P.
3.2.2 Chute/Balloon Mechanical Connection, OF-322-40-P.
3.2.3 Assembly/Tensioning, OF-714-00-P.
3.3.1 Zero failures out of 160 flights to bring system to ground, per FTSR, 820-FTSR-2011-1.
3.4.1 Per procedure OF-106-10.
4.1.1 In accordance with OF-322-10-C (ZPB) or OF-322-20-C (SPB), Launch Director's Checklist.

4.2.1 Per FTSR, 820-FTSR-2011-1.

VERIFICATION STATUS

1.1.1 CLOSED 1.1.2 CLOSED. 1.1.3 CLOSED 1.2.1 CLOSED. 1.3.1 CLOSED. 1.3.2 CLOSED 1.4.1 CLOSED. 1.4.2 CLOSED. 1.5.1 CLOSED. 1.5.2 CLOSED. 2.1.1 CLOSED 2.2.1 CLOSED. 2.3.1 CLOSED. 2.3.2 CLOSED. 2.3.3 CLOSED. 2.3.4 CLOSED. 2.4.1 CLOSED 2.5.1 CLOSED. 2.6.1 CLOSED. 3.1.1 CLOSED. 3.2.1 CLOSED. 3.2.2 CLOSED 3.2.3 CLOSED. 3.3.1 CLOSED. 3.4.1 CLOSED. 4.1.1 CLOSED 4.2.1 CLOSED

INITIAL RISK SEVERITY I ***INTERIM RISK SEVERITY*** I

INITIAL MISHAP PROBABILITY C ***INTERIM MISHAP PROBABILITY*** D

INITIAL RISK ASSESSMENT CODE 1 ***INTERIM RISK ASSESSMENT CODE*** 2

FINAL RISK SEVERITY I

FINAL MISHAP PROBABILITY E

FINAL RISK ASSESSMENT CODE 3

NOTES/COMMENTS

Reviewed 7/24/18 T.Moskios/Code 803 Disposition: Significant Modifications

Hazard Analysis Report

HAZARD REPORT NUMBER Balloon HR-31

PROJECT Balloon ***AUTHOR*** Moskios/Salter/Maxfield/Ball

ID ***LAST MODIFIED*** 7/20/2018

HAZARDOUS SUBSYSTEM/OPERATION
Balloon Flight Operations

HAZARD DESCRIPTOR
Premature termination caused by lightning.

HAZARD DESCRIPTION
Thunderstorm activity during ascent or float phases leads to premature initiation of terminate system due to lightning.

HAZARD CAUSE
1. Lightning causes premature initiation of terminate pyrotechnics.
2. Balloon flies too close to thunderstorms during ascent phase or floats phase.

HAZARD EFFECTS
Death, injury, property damage, danger to commercial and general aviation.

HAZARD CONTROLS
1.1 EEDs meet NASA specifications for explosives. Shorted, shielded and grounded bridge wire leads, and 1A/1W no fire.
1.2 Firing circuit must meet Range Safety Manual requirements. Firing circuitry is compliant with Mil-STD-1576 in terms of grounding, shielding, and bleed resistors to protect against ESD.
1.3 Staticide applied to parachutes to prevent electrical charge buildup.
2.1 CSBF procedures prohibit launch if thunderstorms are forecast in the vicinity of the predicted ascent trajectory.

CONTROLS VERIFICATION
1.1.1. PSEMC initiator and 6803 specifications provided in Balloon System FTSR, 820-FTSR-2011-1.
1.2.1. Firing circuits provided in the GS RAR, 803-GS-RAR-BPO-Balloons-01H.
1.3.1 Staticide applied per OF-322-10-C, Launch Director's Checklist.
2.1.1 Forecasts of ascent and float weather discussed in depth at pre-launch weather briefings, per OF-322-10-C, Launch Director's Checklist.
2.1.2 Enroute weather updated throughout flight by CSBF meteorologists, per OF-322-10-C, Launch Director's Checklist.

VERIFICATION STATUS
1.1.1 CLOSED 1.2.1 CLOSED. 1.3.1 CLOSED. 2.1.1 CLOSED. 2.1.2 CLOSED.

INITIAL RISK SEVERITY I ***INTERIM RISK SEVERITY*** I

INITIAL MISHAP PROBABILITY C ***INTERIM MISHAP PROBABILITY*** D

INITIAL RISK ASSESSMENT CODE 1 ***INTERIM RISK ASSESSMENT CODE*** 2

FINAL RISK SEVERITY I

FINAL MISHAP PROBABILITY E

FINAL RISK ASSESSMENT CODE 3 ***NOTES/COMMENTS:*** Reviewed 07/20/18, T.Moskios/Code 803, Disposition: Added documentation

Hazard Analysis Report

HAZARD REPORT NUMBER Balloon HR-32

PROJECT Balloon ***AUTHOR*** Moskios/Salter/Maxfield/Ball

ID ***LAST MODIFIED*** 7/16/2018

HAZARDOUS SUBSYSTEM/OPERATION

Balloon Flight Operations

HAZARD DESCRIPTOR

Critical flight control telemetry loss.

HAZARD DESCRIPTION

Loss of critical flight control telemetry data leads to a possible unplanned termination.

HAZARD CAUSE

1. Critical flight telemetry is lost due to battery/LDB solar power system failure.
2. Critical flight telemetry is lost due to software or hardware malfunction.
3. Common cause failure, such as the GPS frequencies are being jammed.

HAZARD EFFECTS

Death, injury to the public, hazard to commercial and general aviation.

HAZARD CONTROLS

1.1 There are at least 3 systems on each mission that send back telemetry data: UTP; CIP, SIP, or MIP; Balloon tracker; and, a FAA transponder, which is not on all missions. Each of these systems will have their own independent battery packs.

1.2 Only approved batteries with lengthy flight history in the anticipated environment are used. Battery systems are redundant for critical telemetry systems (UTP). Batteries are de-rated if necessary based on expected environmental conditions

2.1 At least 3 systems are required to fail for there to be a telemetry downlink failure: UTP; CIP, SIP, or MIP; Balloon Tracker; and a FAA tracker (on some missions). Backup navigation system provides balloon position and altitude in case of primary, secondary, and tertiary system failure.

2.2 Hardware undergoes pre-flight environmental testing.

2.3 Hardware and software undergo pre-flight functional testing.

3.1 Missions systems launched in the S.W. US (i.e. Palestine and Ft. Sumner) are outfitted with GLONASS receivers, which are on a different frequency than standard US GPS receivers.

3.2 Campaign Manager plans missions around DoD facility jamming activities.

CONTROLS VERIFICATION

1.1.1 Documented battery capacity analysis and/or solar power system configuration is presented and reviewed at Mission Readiness Review for each telemetry system.

1.2.1 Documented in Balloon System Flight Termination System Report, 820-FTSR-2011-1.

2.1.1 Telemetry downlink systems are discussed in Balloon System Flight Termination System Report, 820-FTSR-2011-1.

2.2.1 Documented environmental testing of critical flight systems presented at Mission Readiness Review.

2.3.1 Documented pre-flight functional testing (EC-300-11, EC-300-04, EC-300-30, EC-700-11 through EC-700-16, EL-100 series).

2.3.2 Documented software configuration control system for all flight and ground software. (EL-200-00, EL-200-10).

3.1.1 Presented at Mission Readiness Review for each telemetry system.

3.2.1 Documented in Launch Directors Checklist, OF-322-10-C.

VERIFICATION STATUS

1.1.1. CLOSED 1.2.1 CLOSED 2.1.1 CLOSED 2.2.1 CLOSED 2.3.1 CLOSED 2.3.2 CLOSED 3.1.1 CLOSED 3.2.1 CLOSED

INITIAL RISK SEVERITY I ***INTERIM RISK SEVERITY*** I

INITIAL MISHAP PROBABILITY C ***INTERIM MISHAP PROBABILITY*** D

INITIAL RISK ASSESSMENT CODE 1 ***INTERIM RISK ASSESSMENT CODE*** 2

FINAL RISK SEVERITY I

FINAL MISHAP PROBABILITY E

FINAL RISK ASSESSMENT CODE 3

NOTES/COMMENTS

T.Moskios added documentation references, 7/16/18

Hazard Analysis Report

HAZARD REPORT NUMBER Balloon HR-33

PROJECT Balloon ***AUTHOR*** Maxfield/Ball

ID ***LAST MODIFIED*** 9/17/2010

HAZARDOUS SUBSYSTEM/OPERATION
Balloon Flight Operations

HAZARD DESCRIPTOR
Critical flight command control capability loss.

HAZARD DESCRIPTION
Loss of critical flight command control leads to derelict balloon and possible unplanned termination.

HAZARD CAUSE
1. Flight command control is lost due to battery/solar power system failure. 2. Command receiver sensitivity loss due to frequency interference. 2. Flight command control is lost due to software or hardware malfunction.

HAZARD EFFECTS
Derelict balloon, death, injury, property damage, danger to commercial and general aviation.

HAZARD CONTROLS
1.1 Battery packs are sized to provide a ~50% margin on top of anticipated flight duration. Only approved batteries with lengthy flight history in the anticipated environment are used. Battery systems are redundant for critical command systems (UTP). Batteries are de-rated if necessary based on expected environmental conditions. 2.1 Frequency authorization system insures command frequencies are not interfered with by external users. 3.1 Hardware and software undergo pre-flight functional testing. Redundant command receivers for critical flight systems (UTP).

CONTROLS VERIFICATION
1.1.1. Documented battery capacity analysis and/or solar power system configuration is presented and reviewed at Mission Readiness Review. 2.1.1 Documented frequency authorization system administered by WFF frequency coordinators. 3.1.1 Documented thermo-vacuum testing of critical flight systems presented at Mission Readiness Review. Documented pre-flight functional testing. Documented software configuration control system for all flight and ground software.

VERIFICATION STATUS
1.1.1. CLOSED 2.1.1 CLOSED 3.1.1 CLOSED

INITIAL RISK SEVERITY I ***INTERIM RISK SEVERITY*** I

INITIAL MISHAP PROBABILITY C ***INTERIM MISHAP PROBABILITY*** D

INITIAL RISK ASSESSMENT CODE 1 ***INTERIM RISK ASSESSMENT CODE*** 2

FINAL RISK SEVERITY I

FINAL MISHAP PROBABILITY E

FINAL RISK ASSESSMENT CODE 3

NOTES/COMMENTS
Reviewed 06/11/18 L.Wiles/Code 803 Disposition: No Change

Hazard Analysis Report

HAZARD REPORT NUMBER Balloon HR-34

PROJECT Balloon ***AUTHOR*** Maxfield/Ball

ID ***LAST MODIFIED*** 9/17/2010

HAZARDOUS SUBSYSTEM/OPERATION
Balloon Flight Operations

HAZARD DESCRIPTOR
Balloon Aircraft collision

HAZARD DESCRIPTION
Commercial or private aircraft collides with balloon.

HAZARD CAUSE
1. Aircraft collides with ascending/descending balloon.

HAZARD EFFECTS
Death, injury, property damage, or danger to commercial and general aviation.

HAZARD CONTROLS
1.1. Preflight Notice to Airmen (NOTAM) and Prior to Descent Notice filed with FAA or international equivalent.
1.2 Unicom radio announcements made on VFR authorized frequencies for US operations.
1.3 Altitude position reports called into FAA or international equivalent during ascent and descent.
1.4 FAA or international equivalent must give verbal authorization for launch and termination.
1.5 Flight plan is closed out with FAA or international equivalent following impact.
1.6 FAA or ICAO transponder is flown on all flights. FAA or international equivalent is authorized to ask for termination at any time during flight.

CONTROLS VERIFICATION
1.1.1 Documented NOTAMS/Prior to Descent notices, as required by FSP.
1.2.1 Preventative maintenance performed on Unicom transceivers.
1.3.1 Documented checklists for FAA notification on ascent and descent.
1.4.1 Documented approval (authorizing official) for launch and descent approval.
1.5.1 Documented closeout of flight plan.
1.6.1 FAA and ICAO transponders checked with transponder diagnostic equipment prior to launch.

VERIFICATION STATUS
1.1.1. CLOSED 1.2.1 CLOSED 1.3.1 CLOSED 1.4.1 CLOSED 1.5.1. CLOSED 1.6.1. CLOSED

INITIAL RISK SEVERITY I ***INTERIM RISK SEVERITY*** I

INITIAL MISHAP PROBABILITY C ***INTERIM MISHAP PROBABILITY*** D

INITIAL RISK ASSESSMENT CODE 1 ***INTERIM RISK ASSESSMENT CODE*** 2

FINAL RISK SEVERITY I

FINAL MISHAP PROBABILITY E

FINAL RISK ASSESSMENT CODE 3

NOTES/COMMENTS: Reviewed 06/11/18 L.Wiles/Code 803 Disposition: No Change

Hazard Analysis Report

HAZARD REPORT NUMBER Balloon HR-38

PROJECT Balloon ***AUTHOR*** Moskios/Salter/Wiles/Maxfield/Ball

ID ***LAST MODIFIED*** 07/24/2018

HAZARDOUS SUBSYSTEM/OPERATION
Balloon Flight Operations

HAZARD DESCRIPTOR
Balloon or payload impact the public or property following flight termination

HAZARD DESCRIPTION
Balloon or payload impacts personnel or real property after descent following flight termination.

HAZARD CAUSE
1. Error in utilizing documented termination procedures and flight specific safety criteria in the Risk Analysis Report (RAR) unique to each campaign.
2. Acceptable statistical Casualty Expectation risk (100 X 10^{-6}) or Acceptable 'near real time' risk assessment does not take place.

HAZARD EFFECTS
Death, Injury or Property Damage

HAZARD CONTROLS
1.1 Risk Analysis Report (RAR) prepared for each flight by WFF Flight Safety Office delineates acceptable areas for flight trajectory and termination. Balloon Risk Analysis is discussed in Flight Readiness Review meeting.
1.2 Only qualified personnel allowed to perform flight terminations (Campaign Managers, Senior Aircraft Observers).
1.3 Termination plans are discussed immediately prior to termination between Campaign Manager and Senior Aircraft Observer in the aircraft via Iridium or other communication system.
1.4 CSBF tracking aircraft performs aerial surveillance of predicted impact areas prior to termination if possible.
2.1 NASA/GSFC/WFF management sets acceptable risk criteria and reviews periodically.
2.2 Surveillance Aircraft available at launch for operations support of termination event to ensure P(c) criterion is met.
2.3 Use of 'near real time' risk analysis prior to launch as well as color coded relative risk maps in selection of termination point with applied descent vectors to ensure Ec criterion is met..

CONTROLS VERIFICATION
1.1.1 Documented Flight Safety Risk Analysis Report for the campaign.
1.2.1 Documented termination procedures, OF-690-00-P, Conventional Balloon Flight Tracking and Termination Procedures.
1.3.1 OJT training program for Campaign Managers and Senior Aircraft Observers, AS-2015-7.2-G.
1.4.1 Documented Flight Safety Risk Analysis Report for the campaign.
2.1.1 Current acceptable Ec and Pc values are documented in RSM-2002C.
2.2.1 Required by the FS RAR for the campaign.
2.2.2 As documented in OF-690-00-P.
2.3.1 The process of "near real time" risk analysis is documented in the FS RAR for the campaign.
2.3.2 Use of CSBF Standard Operating Procedures in selection of termination point with applied descent vectors to ensure known populations are avoided, per procedure OF-690-00-P.
2.3.3 MRSO should be on duty in control tower or monitoring remotely for termination as documented in campaign Flight Safety Plan.

VERIFICATION STATUS
1.1.1. CLOSED 1.2.1 CLOSED. 1.3.1 CLOSED. 1.4.1 CLOSED 2.1.1 CLOSED 2.2.1 CLOSED 2.2.2 CLOSED.2.3.1 CLOSED 2.3.2 CLOSED. 2.3.3 CLOSED

INITIAL RISK SEVERITY I ***INTERIM RISK SEVERITY*** I
INITIAL MISHAP PROBABILITY B ***INTERIM MISHAP PROBABILITY*** C
INITIAL RISK ASSESSMENT CODE 1 ***INTERIM RISK ASSESSMENT CODE*** 2

FINAL RISK SEVERITY I
FINAL MISHAP PROBABILITY E
FINAL RISK ASSESSMENT CODE 3

NOTES/COMMENTS

Reviewed 07/24/18 T.Moskios/Code 803 Disposition: included documentation.

Hazard Analysis Report

HAZARD REPORT NUMBER Balloon HR-39

PROJECT Balloon **AUTHOR** Moskios/Salter

ID A1A **LAST MODIFIED** 7/19/2018

HAZARDOUS SUBSYSTEM/OPERATION

Balloon Launch Abort Operations

HAZARD DESCRIPTOR

Personnel injury during nominal launch abort.

HAZARD DESCRIPTION

Once a balloon launch abort is called (by definition prior to a payload release from the launch vehicle), personnel may be injured who are in the launch danger area. Launch abort comes in two varieties: 1) passive abort—helium is released from the valve(s) at the top of the balloon; and, 2) active abort—the parachute is cut from the balloon at the terminate fitting when the balloon termination system is activated. The crew chief determines what type of abort.

HAZARD CAUSE

1. Injury to essential personnel due to contact with balloon material or flight train; or,
2. injury to non-essential personnel due to contact with balloon material or flight train.

HAZARD EFFECTS

Injury when personnel come into contact with the balloon material.
Note: loss of launch opportunity is not a hazard effect since the decision to abort was already made prior to entering into the launch abort operation.

HAZARD CONTROLS

1.1 All essential personnel within the hazard area during a balloon launch ride on the launch vehicle.
1.2 The crew chief can maneuver the LV to ensure that flight train materials are not directly above the launch crew.
2.1 Non-essential personnel are excluded from the launch danger area during a launch.

CONTROLS VERIFICATION

1.1.1 Documented in flightline checklist, OF-322-10-C.
1.1.2 Documented in mission GSP.
1.2.1 Documented in flightline checklist, OF-322-10-C.
2.1.1 Documented in mission GSP.

VERIFICATION STATUS

1 1.1. CLOSED. 1.1.2. CLOSED. 1.2.1. CLOSED. 2.1.1. CLOSED.

INITIAL RISK SEVERITY	II	**INTERIM RISK SEVERITY**	II
INITIAL MISHAP PROBABILITY	C	**INTERIM MISHAP PROBABILITY**	D
INITIAL RISK ASSESSMENT CODE	2	**INTERIM RISK ASSESSMENT CODE**	3

FINAL RISK SEVERITY	II
FINAL MISHAP PROBABILITY	E
FINAL RISK ASSESSMENT CODE	3

NOTES/COMMENTS: New HR